21st CENTURY SCIENCE & TECHNOLOGY

SUMMER 1999

$3.50/IN CANADA $4.50

Back to the Moon with Nuclear Rockets

21st CENTURY SCIENCE & TECHNOLOGY

Vol. 12, No. 2 Summer 1999

Features

Edison National Historical Site, National Park Service

The intense political battle fought by the American nationalist industrialist faction, of which Thomas Edison was a part, comes alive in historian Anton Chaitkin's review of a recent Edison biography, p. 76.

News

Departments

On the cover: A nuclear rocket-powered transfer stage leaving Earth orbit, carrying a passenger transport module on a 24-hour trip to the Moon. Illustration courtesy of Dr. Stanley Borowski/NASA; cover design by Rosemary Moak.

21st Century Science & Technology (ISSN 0895-6820) is published 4 times a year in 1999, every third month, by 21st Century Science Associates, 60 Sycolin Road, Suite 203, Leesburg, Va. 20175. Tel. (703) 777-7473.

Address all correspondence to **21st Century**, P.O. Box 16285, Washington, D.C. 20041.

Second-class postage is paid at Leesburg, Va. and additional mailing offices.

21st Century is dedicated to the promotion of endless scientific progress, all directed to serve the proper common aims of mankind.

Opinions expressed in articles are not necessarily those of 21st Century Science Associates or the scientific advisory board.

We are not responsible for unsolicited manuscripts.

Subscriptions by mail are $25 for 6 issues or $48 for 12 issues in the USA and Canada. Airmail subscriptions to other countries are $50 for 6 issues. Back issues are $5 each ($6 foreign). Payments must be in U.S. currency.

POSTMASTER: Send address changes to 21st Century, P.O. Box 16285, Washington, D.C. 20041-0285.

Printed in the USA ISSN 0895-6820

Science and National Security

The individuals that produced (or believe) the Cox Report suffer from the same fatal flaw as those who campaign to downsize America's national laboratories: They have no idea what real science or real national security is.

On the question of science, as we have stressed in many different articles, scientific discovery is not a matter of amassing "facts" and complex computer programs in which to logically array them, or patenting recipes for inventions.

Scientific discovery occurs because there are minds absorbed in solving a problem, posing a paradox, and sticking with it, concentrating on finding a solution, and freely discussing their ideas with others. The history of the U.S. national laboratories, the science cities of Russia and Japan, and the great university research laboratories demonstrates the potential for continuous advances in science and technology to keep a strong economy growing—which is the only the source of true national security.

The Cox Report is aimed at destroying the Clinton administration's policy of engagement with China, the world's most populous nation, and the leading nation today that is putting into practice the American System methods—investment in science, technology, and infrastructure projects—that built America as an industrial, science-based nation.

No scientists contributed to the *opinions* of the Cox Report. It is, to use the words of Democratic Presidential precandidate Lyndon LaRouche, "a scientifically illiterate hoax," which, with no factual basis, alleges that leaks from U.S. national laboratories enabled the Chinese to develop sophisticated defense technologies. The arguments and nonscience presented by the Cox Report are ludicrous. Their effect will be to further constrict research on the frontiers of science at our national laboratories—advanced nuclear science, fusion energy, and many other new areas. In short, U.S. national security, what the minds behind the Cox Report purport to protect, will be severely damaged.

Edward Teller, the nation's leading nuclear weapons scientist, wrote in the May 14 *New York Times,* "The right prescription for safety is not reaction to dangers that are arising, but rather action leading to more knowledge, and, one hopes, toward positive interaction between nations." Teller, a former director of the Lawrence Livermore National Laboratory, and the "father" of the U.S. hydrogen bomb, compared the stealing of nuclear secrets by the Soviet Union a half century ago, to the recent allegations that China has stolen U.S. nuclear weapons secrets.

Then, Dr. Teller states, it was very likely that the Soviet nuclear weapons program benefitted materially from the information that had been leaked to Klaus Fuchs, among others. "The situation is in sharp contrast to the present position of the Chinese scientists. They have had 50 years to consider the possibilities that we kept secret. It seems to be probable that the Chinese must have made discoveries that made the added knowledge from intelligence less important."

Teller also compared the reaction to the current accusations by politicians in Washington, to those after the Fuchs case was discovered. Then, Teller recalls, President Truman "imposed no additional measures for security. Instead we have clear knowledge that the disclosures by Fuchs caused Truman to call for accelerated work on all aspects of nuclear weapons." The result was that the United States kept ahead of the Soviet effort.

Teller, who has waged a 40-year campaign to declassify science, laments that the "proposed remedy" today is "more security, including exclusion from participation of people from abroad." He says: "Let us remember that past military successes have been accomplished by remarkable people from abroad—for instance, Enrico Fermi. I claim that our continuing security is acquired by new knowledge rather than by conserving old knowledge."

Letters

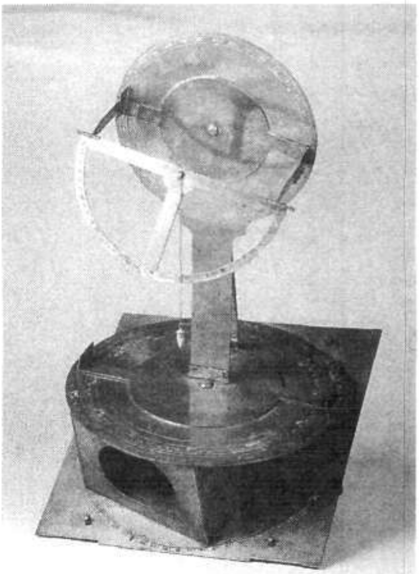
Cusa's Torquetum

To the Editor:

It was a delight to see the astronomical instrument of Nicholas of Cusa, the torquetum, c. 1444, the oldest in Europe, in its earlier version, as designed by Eratosthenes and used by the navigator Maui on a voyage to circumnavigate the Earth in 232 B.C. (Maui's Tanawa: A Torquetum of 232 B.C.," by Dr. Sentiel Rommel, Spring 1999, p. 75.)

Cusa designed his torquetum with the help of Regiomontanus, and it was considered to be too heavy and clumsy for use. Eratosthenes' design is more portable, and has a sundial time-piece on the ring, which is in the plane of the ecliptic.

The best feature of this instrument is that it can mechanically transfer coordinance among three coordinate systems: the direction of a star or planet in celestial latitude or longitude in reference to the plane of the ecliptic; right-ascension and declination in the plane of the equator; and, finally, the local coordinates of horizon and height (that is, azimuth N, S, E, W, and altitude of an object).



Cusa's torquetum, c. 1444, courtesy of St. Nikolaus Hospital, Cusanus Stift, founded 1458 (D-54470 Bernkastel-Kues, Germany).

The torquetum is also said to be valuable because it allows you to examine the shift in the precession of the equinoxes (50.25 seconds of arc per year, or 1 degree every 70 years). I would like to know more about this. Also, the torquetum's companion instrument is the astrolabe. Will *21st Century* also publish something on the astrolabe said to be used by Maui?

Eli Santiago
Ridgefield Park, N.J.

The Editor Replies

Yes, we intend to continue coverage of the ancient astronomy in future issues.

Thanks for the Spring Issue!

To the Editor:

Just a few lines to say that the Spring 1999 issue is outstanding. The "Discovery" articles and "Electric Embryo" were exciting to read and bring into personal awareness. I've never found a dull issue, but this is the first that compels me to send along acknowledgement and thanks.

Stanley Vlantes
Milford, Conn.

A Response to Pradel on Simplifying Radiation Risk

To the Editor:

Let us agree that a risk does not exist until it is well established with solid experimental evidence. There is no evidence to show a risk from low dose or low dose rate whole body radiation for doses less than of 0.2 Gy (20 rads) acute or a much higher dose if spread over months or years. It is a rare dose that exceeds these values.

Pradel, unfortunately, accepts an assumption as a fact. The International Commission for Radiological Protection (ICRP) in 1977 made the simplifying assumption that radiation may be carcinogenic down to zero dose. This is the linear, no-threshold (LNT) model of radiation risk. In 1974, solid data contradicted this model. Frigerio (1974) and Evans (1974) present data that contradict the LNT model. I disagree with Pradel's statement that "Epidemiological studies will never be able to prove that these cancers [at low doses] do, or do not exist. . . ."

Pradel does make some points in his article, but I doubt if many readers will recognize their simplicity. Equating a small exposure from uranium processing to the increased dose from cosmic rays a few meters above our normal living level, or breathing outdoor air rather than indoor air, with its higher radon level, is not an obvious simplification.

I object to Pradel's analogy on two grounds. First, it implicitly suggests that such trifling doses really do have risks, and second, because the cosmic rays and radon level vary considerably with time and place.

Because a large fraction of your readers fly in jet planes, it would be useful to point out that their dose from cosmic rays increases about a factor of 30 in going from sea level to cruising altitude at about 40,000 ft. My geiger counter typically has a count rate of about 10 counts per min (cpm) at the airport, and about 300 cpm at the cruising altitude. This is usually quite impressive to persons sitting next to me, and also to the flight attendants. There is no evidence that an increase of this amount has any negative health effects.

Using an increase of radon level as a risk factor is contradicted by Cohen's data (1995) on radon level vs. lung cancer death rate. I doubt if any person, scientifically trained or not, would look at Cohen's data and decide that reducing your radon level decreases your risk. His data indicate that U.S. counties with radon levels above 5 pCi/l have 40 percent lower lung cancer death rate than the counties with radon levels below 0.5 pCi/l. This suggests that radon progeny in the lungs in some way reduces the risk of a smoker dying from lung cancer.

I suggest that the way to simplify radiation to the public is:

(1) Do not mention risk for doses less than 0.2 Gy (20 rads), because there is no evidence that a risk exists.

Continued on page 86

Can Children of Cyberspace Become Engineers?

by Henry Petroski

So many students majoring in engineering today seem to have few if any experiences with the artifacts of engineering, other than consuming and using them. For example, some students may have significant expertise with regard to interfacing with a computer, and may even engage in a degree of programming and hacking, but the vast majority appear to use the computer as a black box. They seem disinclined to open up the box to see what makes it tick. Neither are they drawn to fix their own cars, let alone their own bicycles.

Indeed, judging from my own experiences with today's affluent first- and second-year engineering students, many of them appear to have led deprived childhoods, when it comes to having learned the innards of machines by taking them apart and putting them together again. Moreover, not a few engineering students seem not to have even handled some of the most basic tools with which to do so. Because they have not had the tactile experience of being mechanics, they also seem to lack the visual sense that develops from it. Thus, when asked to draw a machine part, they are at a loss for lines.

The roots of this problem must certainly lie at least in part in the nature of toys. Whereas the budding engineer once had to wrestle with the nuts and bolts of Erector sets, always planning ahead to be sure the fingers could reach behind the parts of the construction crane, delivery truck, or bridge being assembled, today's youngster commands armies of destruction workers without ever having to construct any one of them. Today's engineering students may have played with Legos, but to the Erector-set veteran, Legos seem more like puzzles than construction toys. As a rule, today's future engineers play electronic games, rather than design them. One begins to wonder what these children of cyberspace will do when they encounter the real world of engineering, which does not come with prepackaged software or with everything preprogrammed.

A recent informal survey of American business leaders who began their careers as engineers, found that many of them recall with fondness playing as children with chemistry sets and construction toys, such as Lincoln Logs, Tinker Toys, and Erector sets. In addition to using these packaged training kits, many remember being interested in how things work. According to Wayne Allen, a mechanical engineer who is chief executive of Phillips Petroleum, "I frequently would take toys and machines apart, just to know mechanically how they worked, whether it was a bike, go-cart, or car." Whether such activity inspired, or just prefigured an interest in engineering, it is uncannily common and familiar among older engineers.

Toys That Built Engineers

Like many of my war-baby contemporaries, long before I was an engineering student, I played with Erector sets, those steel construction toys whose parts were modelled after real girders and their fittings. The Erector set presented a considerable challenge in construction management, for there were no step-by-step plans to follow from a box of parts to an assembled structure. There were drawings on the box, in advertisements, and in the catalogues of the manufacturer, the A.C. Gilbert Company, of course, showing what could be achieved with the standardized parts, but these did not tell would-be engineers where to start, or what pitfalls to avoid.

With a screwdriver and a wrench, we were expected to see the task through, from beginning to end. The supreme design challenge came when we had only a picture in our mind's eye of some great bridge or tower of our own devising, some great structure whose lines changed as we used up the parts in the Erector set. Our British counterparts have similar recollections of Meccano sets. These were the toys that built engineers.

Many of us also played with electric trains, taking apart locomotives and accessories, seeing how they puffed smoke and lowered crossing gates, learning at the same time how the parts fit together to make a whole. My brother, who also became an engineer, and I spent many a rainy afternoon and school vacation designing, planning, and laying out new track arrangements, always working under the constraints of limited basement floor space, too few sections of straight or curved track, and never enough switches of the correct handedness to build the dream model-railroad yard.

After Erector sets and electric trains, there were bicycles to assemble and disassemble.

Little did I know it then, but tinkering with bicycles was preparing me for a career in engineering, as surely as were the mathematics, science, and mechanical-drawing courses I was taking in high school. Even before I took my first laboratory course in school, I was adept at reading plans and using apparatus, for these activities seemed to be just an extension of working with Erector sets, model trains, and bicycles. What united

Henry Petroski is A.S. Vesic Professor of Civil Engineering and a professor of history at Duke University, where he also chairs the Department of Civil and Environmental Engineering.

His new book, The Book on the Bookshelf, *will be published in September by Alfred A. Knopf. This viewpoint is adapted, with permission, from a longer article, "Work and Play," published in* American Scientist, *Vol. 87, May-June 1999.*

all these activities was that they involved design—whether of a track layout, a fanciful tower, or a scheme for aligning a wheel knocked askew by a pothole. The proof of the design was in the making and doing, of course, just as in the world of real engineering.

My senior year in college brought another dimension to my formal and informal engineering education. As part of our course requirements, each of us students had to carry out an independent project in which we designed and built something on our own. There were few guidelines and no given boxes of track or sets of girders. I recall coming up with several ideas. One was a scheme to assemble a photoelastic polariscope, whereby under polarized light, plastic models of loaded beams and gears would reveal their stress patterns.

There were no polarizing filters, quarter-wave plates, or other necessary optical equipment available at the college, however, so I had to identify a source for them and see if they could be purchased within a reasonable budget. This was all considered part of what the project was to teach us green engineers about real engineering.

The Yellow Pages revealed a nearby source of the equipment, and one afternoon I visited the J. Klinger Scientific Apparatus Corporation to check on the quality, price, and availability of what I needed. Klinger's was a storefront operation, in which the desk of the principal, Jakub Klinger, occupied one of the window bays that I imagined once displayed the shoes, appliances, and toys sold by the store's previous occupants. The store space proper was given over to the staff who processed paperwork, and clerks who filled orders from schools, colleges, and research laboratories.

"It didn't come with software, you fix it yourself."

By some odd congruence of needs, Mr. Klinger was in the process of producing a book of experiments to distribute to schools, and thereby encourage them to purchase the equipment he stocked. Among the experiments was one on photoelasticity, and he asked if I would be interested in building a polariscope for him and designing experiments that involved its use. I accepted his offer and began working in the shop each afternoon after school, having the entire stock in the basement at my disposal.

How typical were my experiences? I believe a good number of engineers of my generation and older did play with Erector sets, electric trains, and bicycles, not to mention chemistry sets, radios, electronics kits, Heath kits, and the like, as the survey of engineers-turned-business-leaders so strongly shows.

Remedial Engineering

Many of my peers in engineering education today agree that youthful experiences like the ones I have described are all too often a thing of the past. Too many students appear now to choose engineering for reasons having nothing to do with the joy of building, or taking apart, the things of their childhood. Rather, they appear to choose engineering for a host of reasons ranging from its being a practical major that will lead to a job after college, to its being an idealistic major that will enable them to help clean up the environment. These are not inappropriate reasons, of course, but they do not in themselves provide any evidence of a propensity toward the essence of engineering: designing and building things.

Because these concerns are widespread, at least among my generation, some engineering educators are coming to assume that virtually all incoming students are deficient in real tactile, spatial, and mechanical experiences. Thus, what might be called remedial play courses have been developed. One such course is taught at Stanford University under the title Mechanical Dissection. In it, students disassemble and then reassemble such machines and devices as laser printers, fishing reels, and ten-speed bicycles. The hands-on experiences are intended to provide a feel for engineering that a generation or two ago students would have brought with them to the classroom.

It remains to be seen if such remedial activity will produce as many engineers who become business leaders as did my generation's untrammeled use of chemistry sets and construction toys.

Jackie McBride/LLNL

NIF's target chamber in transit.

NIF TARGET CHAMBER UNVEILED AT LAWRENCE LIVERMORE NATIONAL LAB

The 150-ton target chamber for the National Ignition Facility (NIF), the inertial confinement fusion device now under construction at Lawrence Livermore National Laboratory, was unveiled by U.S. Energy Secretary Bill Richardson June 11. The 35-foot diameter target chamber was hoisted by a crane and positioned in the Target Building. NIF, which is scheduled for completion in 2003, will have 50 times the power of any laser in use today.

BUILD BRIDGES WITH CHINA, COMMERCE OFFICIAL SAYS

In a June 16 interview with Associate Editor Marsha Freeman, Undersecretary of Commerce, Bureau of Export Administration, William Reinsch scored attempts on Capitol Hill to treat China as the new Cold War adversary. "I think there's been a tendency among some in the Congress to try to draw a Cold War analogy between China and the Soviet Union in the 1950s," he said. "The Soviet Union participated in walling itself off from Western influence, Western economics, Western finance, and really created a second camp, and articulated an alternative ideology and world view. The Chinese are really doing the opposite, as far as economics is concerned. . . . One of President Kennedy's theories about these things was that the way to reach better relationships was to build bridges. You start out building cultural and economic bridges because those are the easiest ones to build. Each time you build a bridge, you increase the stake in the relationship and you increase the cost of disrupting the relationship. Each little bridge that you build, even the smallest, becomes one more thing that binds us together and gives us incentives to work on our differences peacefully, rather than become adversaries. That's what we've been trying to do with the Chinese."

"The assumption that they are going to be an enemy would essentially turn the last 20 years of strides [in building bridges], ever since 1979, on its head, and move our policy in the opposite direction."

KRA CANAL FEASIBILITY STUDY PROPOSED BY JAPAN'S GIF

A delegation from Japan's Global Infrastructure Fund (GIF) visited Thailand in early June to present its proposal for a feasibility study of the 10-km canal project that would link the Indian and Pacific Oceans—an alternative route to the Malacca Straits that would save about 900 miles in shipping transport in Asia. The project was first proposed in 1793, in the reign of King Rama I of Siam. The GIF team met with cabinet ministers and senior officials and the heads of major political parties. As reported in the Singapore *Straits Times,* June 15, a GIF spokesman said, "Judging from our meetings, I can say there is widespread support from all parties for the Kra Canal."

S. DAVID FREEMAN WINS GREEN BOOBY PRIZE FOR 'GREEN LA' PROGRAM

This issue's Green Booby prize goes to S. David Freeman, former head of the Tennessee Valley Authority, and now general manager of the Los Angeles Department of Water and Power, for continuing a 20-year career of catering to the lowest common green denominator. This time, Freeman has launched "Green Power for a Green LA," a program that "offers customers the opportunity to purchase clean energy from renewable sources such as the sun, wind, and water." Initially, according to a press release, "Green Power customers will pay a small premium to cover the cost of developing new renewable energy sources," but, in return, they will get "a menu of energy efficiency measures to help . . . reduce monthly consumption of electricity, and thus reduce their bills and offset the increased cost of Green Power."

RESOLUTION ON PEACE THROUGH DEVELOPMENT FOR THE BALKANS

In a resolution now circulating worldwide, the Schiller Institute has called for a Marshall Plan for the Balkan region, using the already existing postwar reconstruction plans for Bosnia-Hercegovina and the region as an integral part of the overall Eurasian Land-Bridge development program. Projects include full rehabilitation of the Danube water connection as the most important European waterway, and linkage of the Danube to the rivers Morava and Vardar, thereby establishing navigable waterways through Serbia, Macedonia, and Greece to the Aegean Sea. The resolution also demands "an approach to reform of the world monetary and financial system by creating an architecture of the "New Bretton Woods" with no delay (i.e. fixed exchange rates, protection of national economies, and sovereign credit generation for economic development," and "an urgent and sharp break with the IMF and World Bank practice of imposing austerity measures and unacceptable financial conditionalities on sovereign nations."

The resolution was issued by Helga Zepp-LaRouche, founder of the Schiller Institute, and Faris Nanic, Secretary-General of Bosnia's Party of Democratic Action in Croatia, and former chief of staff of President Alija Izetbegovic of Bosnia-Hercegovina in 1996; it now has prominent endorsers from many countries, including many U.S. state legislators and former U.S. congressmen.

For more information, contact the Schiller Institute, P.O. Box 20244, Washington, D.C., 20041, Tel. (202) 544-7018.

Existing and proposed waterways in Balkan countries.

PAKISTANI NUCLEAR SCIENTIST URGES MUSLIM WORLD TO GO NUCLEAR

Dr. Abdul Qadeer Khan urged the 57 Muslim nations to invest in the field of nuclear technology and the promotion of science and technology in general. "An energy-deficient Muslim world can bring [about a] revolution in the lives of its people if nuclear technology is used in an effective way," the Pakistani nuclear scientist said, as quoted in the Pakistani daily *The Nation* on May 31.

AMERICAN NUCLEAR SOCIETY ISSUES POLICY STATEMENT ON LNT

"There is insufficient scientific evidence to support the use of the [LNT, or linear no-threshold model] in the projection of health effects of low-level radiation," the American Nuclear Society stated in its long-awaited Policy Statement on Low-level Radiation, issued in June. The ANS recommends that "an independent group of scientists, medical experts, and health researchers should be established to conduct an open scientific review of all data and analyses on the subject." As noted in this issue's Nuclear Report, p. 13, the existing committees dealing with the subject do not meet the necessary standard of "independent."

In addition, in its June letter to the Nuclear Regulatory Commission on the LNT, the Advisory Committee on Nuclear Waste stated that the use of the LNT "is vigorously challenged."

ANCIENT RUINS IN NEW ENGLAND SURVEYED AT NEARA CONFERENCE

Many different ancient New England ruins were discussed at the 35th annual conference of the New England Antiquities Research Association (NEARA) on April 16-19, from a 2,000 B.C. astronomical observatory (Mystery Hill in New Hampshire, known as America's Stonehenge) to the Newport (Rhode Island) Tower, a huge structure possibly dating from the 1300s, with sighting lines and astronomical alignments. The conference took place in Seekonk, Mass.

The Mystery Hill site was reviewed by Dr. Louis Winkler, an archaeo-astronomer at Pennsylvania State University. The site functioned as an ancient observatory and religious center, he said. It was used as an observatory from 2000 B.C. until about 300 years ago, first by a culture most probably from the British Isles; second, from 1500 B.C. to 500 A.D., by an advanced American Indian culture; and most recently, from 500 A.D. to 1600 A.D., by possibly a mixed culture of Indians and European Celts.

A review of NEARA's book *Across Before Columbus* appears on p. 84.

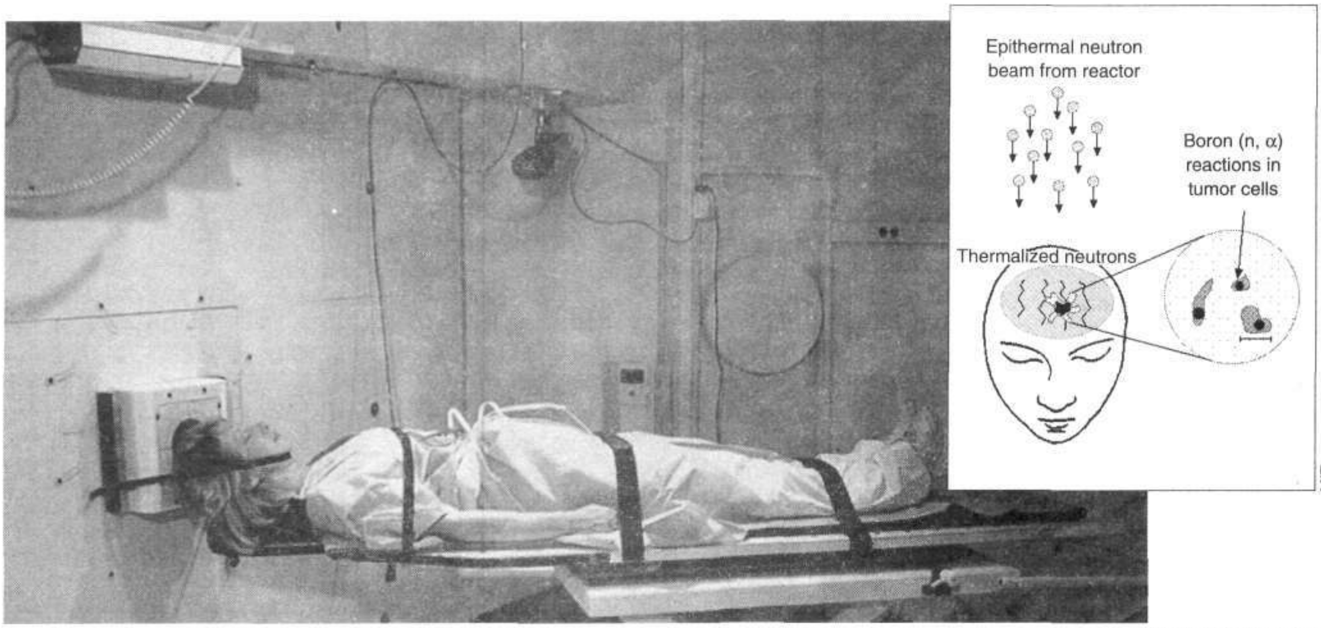
NEARA member Charles Hughes, standing near a stone chamber at Fanstock State Park in Putnam County, N.Y., which possibly dates back to 1,000 B.C. The structure is similar to those found throughout New England, the British Isles, and France.

SPECIAL REPORT

BORON NEUTRON CAPTURE THERAPY

An Elegant Technology That May Save Lives

by Linden Blue



MIT

Brookhaven National Laboratory

Brookhaven's reactor, which has pioneered BNCT clinical studies from the 1960s. In the presence of the neutrons from the reactor, the boron-10 isotope distributed at the tumor site "captures" a thermal neutron and fissions into an alpha particle and a lithium molecule, which then kills tumor cells—a cellular level of tumor control. The boron compounds are then cleared from the body without causing any clinical effects in and of themselves.

There are few more feared words in the world than "cancer." In the United States alone, there are about 4 million patients with currently active disease, 1 million newly diagnosed cases per year, and about 500,000 deaths per year as a direct result of cancer. With aging populations, these numbers are almost certain to get worse.

Mostly thanks to modern science, today many cancer patients are cured and enjoy years of high quality life. For some, cancer implies months of debilitating treatment, followed by remission, followed by recurrence, followed by death. For the least fortunate, it implies a proximate death sentence. Most therapies involve surgery, radiation therapy, or chemotherapy, or a combination of all three. The challenge is usually to destroy tumors without disrupting healthy tissue. Increasingly sophisticated methods for concentrating radiation have proven successful in controlling some cancers.

Despite advances in cancer treatment generally, malignant brain tumors and non-small-cell lung tumors remain intractable. Diagnosis is usually followed by death in a matter of months. Unfortunately, these are the diagnoses for tens of thousands of patients each year in the United States alone. Worldwide, about 300,000 people die from these tumors yearly.

A new kind of therapy has recently shown potential for attacking intractable brain tumors, while minimizing damage to healthy tissue. Boron neutron capture therapy, BNCT, uses an inert, nontoxic isotope of boron, which is carried intravenously to tumors. As soon as optimum levels of boron are delivered by the vascular system to a tumor, the patient is placed in a field of neutrons supplied by either a small research reactor or an accelerator. The neutrons cause the boron to fission, releasing substantial energy in the process, and providing tumor control at the cellular level. The treatment takes less than an hour, and there are very few of the debilitating effects associated with conventional radiation and chemotherapies.

BNCT is scientifically elegant because it combines the potential for the vascular system to distribute an unactivated radiation source that will concentrate in tumors, and concentrated neutrons that will activate the radiation source. In combination, BNCT's radiation effect is lethal to tumor cells, while minimizing the radiation dose to healthy tissue—the first time such an effect has been available for combatting some tumors.

Research treatments funded by the U.S. Department of Energy, and carried out at Brookhaven National Laboratory in New York and the Massachusetts Institute of Technology, have suggested that BNCT is at least as effective as conventional radiation therapy, and prolongs life for several months without debilitating side effects.

New technical-developments make possible a combination of improved boron transport agents and better neutron sources. These improvements will allow a 100 percent increase of the radiation dose to the tumor, above current levels, while giving no additional radiation dose to healthy tissue. This can make a dramatically favorable difference in treatment efficacy, because the challenge in radiation and chemotherapy is to give a large enough dose to kill tumors—without killing the patient. The improvements in BNCT can lift tumor control expectations, for some tumors, substantially.

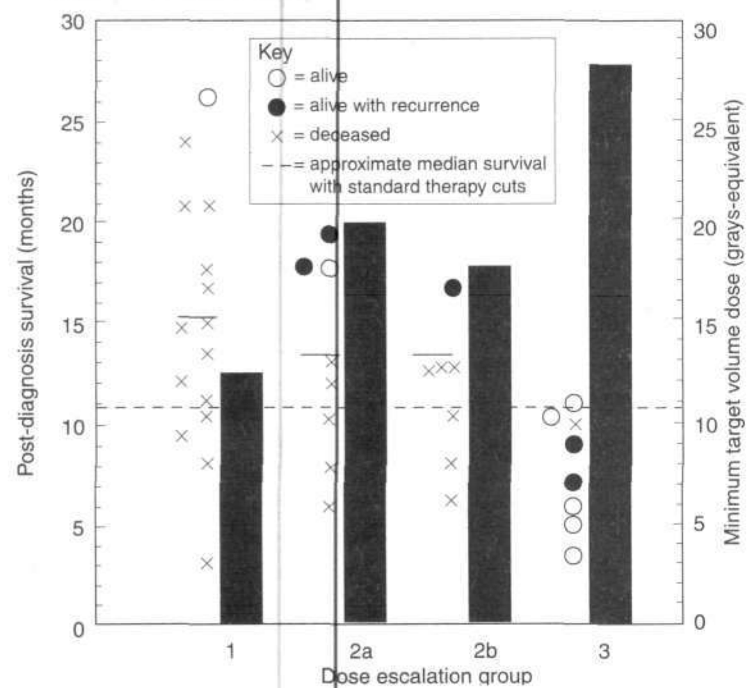


Figure 1
BRAIN TUMOR PATIENT SURVIVAL DATA, BNCT AND STANDARD THERAPY

These data are for BNCT patients in clinical trials, as of March 1998. The vertical black bars indicate dose levels.

Source: BNL

A Clinical History

Neutron radiotherapy has been largely developed in the national laboratories (Brookhaven, Idaho National Engineering & Environmental Laboratory), MIT, and other universities funded by the Department of Energy at a cost of several tens of millions of dollars over many years.

The clinical history of BNCT is linked to two individuals, William H. Sweet and Hiroshi Hatanaka. It was Sweet who first realized the clinical potential of BNCT for treating brain tumors. The pioneering work of Sweet and his colleagues at the Massachusetts General Hospital, the Massachusetts Institute of Technology, and the Brookhaven National Laboratory, in the 1950s and early 1960s, was directed toward treating patients with recurrent high-grade gliomas (very aggressive brain tumors) using several different boron compounds as the neutron capture agent. Unfortunately, none of these compounds demonstrated the requisite tumor selectivity that is now known to be desirable.

Although the clinical results were disappointing, attempts to identify boron compounds that demonstrated a higher degree of tumor selectivity continued on into the mid-1960s. The clinical studies in the United States were stopped in the early 1960s, to be taken up again in the 1980s, but Hatanaka's effort in Japan continued from 1968, until his death in 1994. The Japanese program continues today, although limitations on Japanese reactor time have slowed the clinical use of BNCT. In the past 25 years, Japan has treated only 120 patients, a rate of treatment that is not in the range of commercial clinical applications.

The European effort, led by W. Sauerwein and D. Gabel, began treatments in early 1998. Results are expected to be similar to those at Brookhaven.

The early work, in the 1960s, used borate salts and a "thermal" (low energy) beam of neutrons; later efforts focussed on the development of an "epithermal" (higher energy) neutron beam and more complex boron compounds. The Brookhaven Medical Research Reactor was modified in the late 1980s to produce epithermal neutron beams, and today is conducting clinical trials, focussed on glioblastoma multiforme, the most aggressive type of brain tumor. There is a smaller clinical program using BNCT with the MIT research reactor, for treatment of melanoma and, more recently, brain tumors.

The results of irradiation at Brookhaven (Figure 1) suggest life extensions similar to, or greater than, those of conventional radiation therapy, while anecdotal evidence suggests that the quality of life for Brookhaven's BNCT patients is considerably better than for patients who undergo conventional radiation therapy and chemotherapy for intractable tumors.

Although the Brookhaven results to date suggest that BNCT is as good as, or 10 to 20 percent better than conventional radiation therapy, results are still below potential. For example, Figure 2 shows the relationship of tumor control probability to radiation dose. New and superior radiation sources, combined with new, nontoxic pharmaceutical agents that respect the blood-brain barrier, have the potential of doubling the radiation dose to brain tumors and tumor tentacles—improvements that should have a profound effect on treatment efficacy.

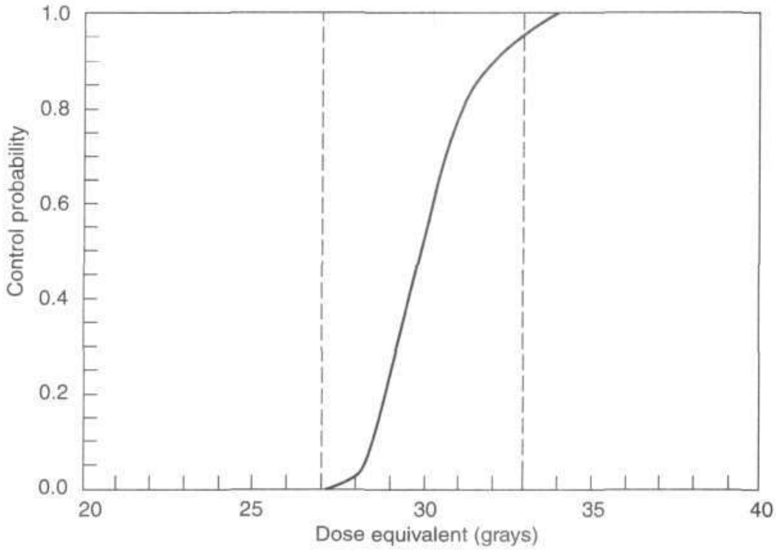


Figure 2
TUMOR CONTROL FOR HIGH-GRADE GLIOMA

As the dose equivalent reaching the tumor is raised, the potential for tumor control rises. New and superior radiation sources, combined with new, nontoxic pharmaceutical agents, have the potential of doubling the radiation dose to brain tumors, thus increasing treatment efficacy.

Source: Dr. George Laramore, University of Washington, 1996.

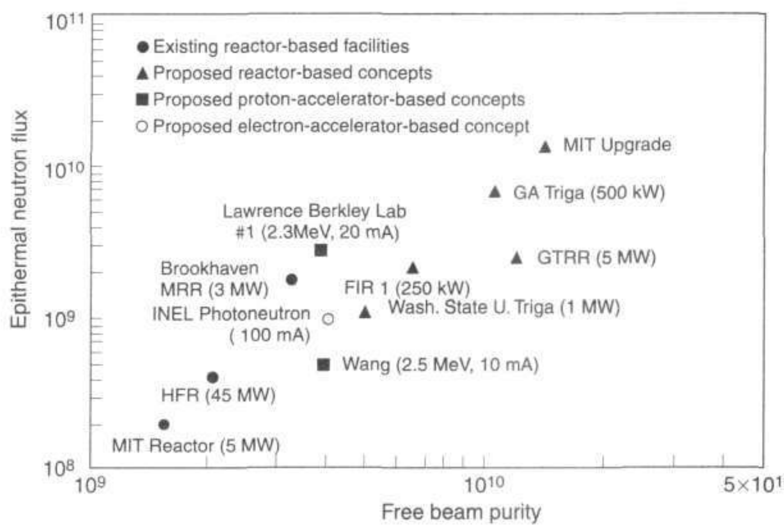


Figure 3
COMPARISON OF SELECTED EPITHERMAL NEUTRON BEAMS

Compared here are the neutron energies for BNCT from existing and proposed reactor and accelerator sources. The low-energy range, the thermal neutron range, was the initial focus of BNCT. Today, a variety of neutron sources is available.

Reactor Neutron Sources

When Professor Sweet started his work at MIT, using simple borate salts and thermal neutrons, the most intense source of neutrons was nuclear reactors. The total number of neutrons required for therapeutic value is about 1×10^{13} neutrons/cm^2. In the early studies, and even up to the present time in the Japanese studies, the low-energy thermal neutrons required that the patient have the skull bone flap over the tumor removed, under anesthesia, and undergo an inter-operative irradiation, so that the neutrons would penetrate to the tumor site.

The low "flux" (neutrons/cm^2/sec) of the available nuclear reactors in the early studies required many hours of irradiation. Because of the interactions of the neutron beam with tissues, the number of neutrons falls off as the beam penetrates tissue. For the early reactor-based neutron sources, the thermal beam lost about half of its intensity in a little more than 3 cm. This neutron dose fall-off was largely responsible for the need for inter-operative procedures.

The energy of neutrons ranges from 10^{-1} to 10^{8} electron volts (eV). The low-energy range, from 10^{-1} to about 1 eV, the thermal neutron range, was the initial focus of BNCT. The energy range from about 5 eV to 10 keV has been identified as the epithermal neutron energy range, with clinical applications again focussed on gliomas and melanomas.

These higher energy epithermal neutron sources, although still reactor-based sources, provided a very important clinical benefit: These neutrons were able to penetrate the intact skull and provided a treatment depth of about 5 to 7 cm, thus eliminating the need for inter-operative irradiation.

The thermal and epithermal neutron beams are proven reactor-based sources, and significant development work is being done to provide new filters, which make it possible for small research reactors to produce superior epithermal neutrons. One research reactor, located in Helsinki, Finland (indicated as GA Triga in Figure 3), has been modified for providing extremely high quality epithermal neutrons for BNCT.

Fast Neutrons

In contrast to the reactor-based thermal and epithermal neutron sources, which have very little radio-therapeutic value in the absence of boron capture, fast-neutron sources have a proven clinical benefit even without boron capture. Fast-neutron radiation therapy was used as a cancer treatment tool at Lawrence Berkeley Laboratory as early as 1938, and has developed over the years so that there are now about 10 fast-neutron sources around the world. In the United States, these sources are located at the University of Washington (the preferred site for initial clinical studies of BNCT-boosted therapy for Stage III lung tumors), and in Detroit, at the Harper Grace Hospital.

There are eight additional fast-neutron therapy units located in Essen, Orleans, Brussels, and Nice in Europe; Chibam, Riyadh, and Seoul in Asia; and Capetown in Africa.

Clinical fast-neutron accelerators are designed to provide neutrons in the 10 to 100 MeV range—energy which cannot be obtained from a fission-based nuclear reactor. These accelerators are generally designed to accelerate protons or deuterons to high energy, and then have them impact a solid target to generate the high-energy neutrons.

For clinical applications, fast-neutron radiotherapy has shown benefit for salivary gland (treatment of choice), prostrate (improvement over conventional radiotherapy), and soft tissue sarcomas, along with a subset of non-small-cell lung cancers.

BNCT Computational Dosimetry

Delivering neutron radiotherapy effectively to the tumor depends upon the ability to maximize the quantity of neutrons that reach the boron agent, which is localized at the tumor site on an optimized dosing regimen. This is accomplished through complex computer programming, such as that developed over the past 10 years at Idaho National Engineering and Environmental Laboratory (INEEL).

Radiation transport and dose distribution analysis for BNCT and for BNCT-augmented fast-neutron therapy is more complex than for photon therapy or for standard fast-neutron therapy. There are several different physical radiation dose components associated with BNCT, each of which has a characteristic spatial distribution and biological effect. Accordingly, many of the simplifying assumptions that would work well for radiation transport calculations associated with photon therapy—and to some extent fast-neutron therapy—are not appropriate for BNCT.

Explicit three-dimensional calculations with a complete treatment of particle scattering are required, both for calculation of the various dose components within the treatment volume, as well as for calculation of the dose components in critical normal tissue structures.

In BNCT, as in photon therapy and fast-neutron therapy, it is important to perform detailed planning calculations in order to optimize the treatment for each individual patient. The goal is to deliver the highest possible therapeutic radiation dose to the target tissue, while maintaining the surrounding healthy tissue at or below tolerance. In BNCT-enhanced fast-neutron therapy, there is an even greater necessity for careful planning, because of the requirement that both the geometrically targeted fast neutron component of the therapeutic dose, as well as the BNCT component, be optimized to the extent practicable.

Without this software, the clinicians, (medical physicists and radiation oncologists) could not perform the radiotherapy. The individualized treatment planning starts from medical images (magnetic resonance imaging, MRI, and computerized tomography, CT, scans), combining these two-dimensional images into a three-dimensional model, and then optimizing the dose distribution of the multiple dose components in the patient.

The INEEL treatment planning software is the *de facto* standard around the world in all of the research institutions involved in BNCT research.

Boron Chemistry and BNCT Agents

Because the BNC reaction is specific for the boron-10 isotope (which occurs naturally in a 20 percent abundance), it is necessary to enrich BNCT agents in this isotope to the greatest extent commensurate with expense and the efficacy of the agent in question. Boron-10 that is more than 95 percent isotopically pure is commercially available from Eagle-Picher in the form of boric acid, $^{10}B(OH)_3$. The most well developed BNCT agents—BPA, BSH, and NT GB-10—are all derived from this source of boron-10-enriched boric acid.

As driven by the physics of boron neutron capture, the boron concentration in the tumor must be at a minimum of approximately 30 micrograms ^{10}B/gram of tissue (30 ppm) to provide a clinical benefit in tumor control. The boron compounds should exhibit low toxicity, selective distribution into tumors and away from normal tissue, and should be retained in the tumor mass at the time of neutron irradiation.

The Food and Drug Administration has recognized these unique requirements by placing the approval process for both the boron compound and the clinical neutron source in the Center for Drug Evaluation and Research (CDER), Division of Medical Imaging, Surgical, and Dental Drug Products, which is the division that approves the enhancement agents and contrast agents for CT and MRI studies.

At this time, three boron-10-enriched agents suitable for use in boron neutron capture therapy are under development: L-p-dihydroxyborylphenylalanine (BPA), $Na_2B_{12}H_{11}SH$ (BSH), and $Na_2B_{10}H_{10}$, (Neutron Therapies' NT GB-10). The boron agents used between 1950 and 1965 were compounds of low boron content, such as boric acid, $B(OH)_3$, and arylboronic acids, $ArB(OH)_2$, where Ar is an aryl group such as p-chlorophenyl. While today's NT GB-10 and BSH are both polyhedral ions and contain 64 percent and 57 percent boron by weight, respectively, the arylboronic acid BPA contains only 4.8 percent boron by weight.

The boron agents that are of current developmental interest fall into two classifications:

The first type are essentially nontoxic, very high in boron content, and do not cross the blood-brain barrier or the membrane that similarly protects the spinal column. Such agents require little targeting specificity other than some selective retention in tumors, because adjacent critical tissues, such as the brain or spinal column, are protected from collateral damage by the barrier membranes that exclude the boron compounds.

The second type are of high-boron content and are capable of providing 30 ppm of boron-10 by weight to the tumor, with high selectivity. Examples of this type would be liposomes, which can have boron agents encapsulated in the aqueous core, or derivatives of boron agents incorporated in the membrane structure. Newer agents based upon phosphate diester trailers and equipped with structural features that provide intranuclear targeting, such as DNA binding, are additional examples of this agent type.

Regardless of the nature of the boron compound, all new agents are initially evaluated in tumor-bearing animals. A suitable animal model is BALB/c mice bearing EMT6 mammary adenocarcinoma, which has been used in most of the screening for liposomal delivery and "trailer" derivatives. Data collected include time-course biodistribution of boron, as determined from direct tissue analyses using inductively coupled plasma-atomic emission spectroscopy (This technology is reliable at concentrations as low as about 0.1 ppb in tissue.)

Tumor, blood, liver, and spleen are routinely screened in the mouse model. Additional tissues are analyzed in follow-on biodistribution experiments. These preliminary mouse experiments allow any existing acute toxicity to be determined. If a promising agent is identified in the preliminary screening, it is then evaluated for biodistribution in larger animals, beginning with tumor-bearing rats, and progressing to dogs with spontaneous tumors of a type suitable for the particular agent.

Radiation Biology

The current design of all forms of radiotherapy is based on the identification of the extent of the invasion of the tumor into normal tissue. The "size" of the tumor is defined from CT scans and MRI scans, with and without enhancing agents. Modern radiotherapy, which includes photon radiation and various particle radiotherapies, such as fast-neutron radiotherapy, can kill what can be "seen."

Techniques such as stereotactic radiosurgery with linear accelerators or the "gamma knife" can provide highly localized tumoricidal doses. The rationale for modern radiotherapy is to improve the delivery of a tumoricidal dose without exceeding the tolerance of normal tissue, which is unavoidably exposed to radiation during treatment.

The dictate of not exceeding the tolerance of normal tissue is the basis of many isocentric techniques, wherein the therapeutic beam is centered on the tumor mass through various rotational-based entry points. Thus, while the tumor receives multiple doses of radiation, the exposure of any given normal tissue is limited.

By definition, the localization of BNCT radiotherapy is dictated by the distribution of the boron agent. With BNCT, in contrast to conventional radiotherapy, the ability and need to "see" the tumor margins for effective radiotherapy is reduced. The neutron "beam" is a misnomer, because the "beam" is, in fact, a diffuse cloud of thermal neutrons that delivers a tumoricidal effect wherever the boron is distributed; that is, only the boron has to "see" the tumor mass.

The history of BNCT radiobiology has focussed on the brain tumor system, using thermal or epithermal neutron beams. The biological effects of these epithermal neutron beams have been largely unstudied. Extrapolation of previous work with thermal beams (often performed in rodents) does not closely enough approximate the mixed-field irradiation encountered in the available epithermal neutron beams, and large-animal models must be utilized in order to study these beams to obtain acute and late tissue effects at an acceptable whole-body radiation dose.

Professor Patrick Gavin at Washington State University has used large-animal models for BNCT in three main areas. The first area is an in-depth study of the pharmacokinetics of the compounds of current clinical interest. The study of pharmacokinetics in large-animal models allows identical administration schedules to those used for human beings, and provides the numerous samples required for thorough pharmacokinetic characterization.

In addition to studies in normal canines, pharmacokinetics have also been studied in dogs with spontaneous brain tumors. Information was obtained from tumor, blood, and normal brain; some studies in terminally ill animals allowed complete sampling of all body tissues. Samples have been obtained from potentially critical tissues including the pituitary, retina, thyroid, and spinal chord. These studies have demonstrated the relationship of the tissue concentration to readily measured blood-boron concentration to facilitate proper treatment planning. Small-animal models cannot provide the tissue mass required for the boron assessment in these tissues.

A second area of study has been the irradiation of spontaneous intracranial tumors in dogs utilizing the epithermal neutron beam. These studies have been an extension of normal tissue tolerance studies and have facilitated the development of appropriate treatment-planning software. These studies have suggested that single dose BNCT can be given safely, and objective tumor response has been measured. Comparison of survival of the BNCT treatment to published reports of conventional radiation treatment of dogs with brain tumors indicates that a single dose of BNCT, given in a standard manner, is roughly equivalent to conventional therapy.

In addition, BNCT has resulted in longer survival of animals with glial tumors, compared to previous reports, and the survival periods were marked with a high quality of life in many animals.

The third area of study has focussed on the development of experimental parameters to support the database on relative biological effectiveness of the various components of epithermal BNCT. In addition to the desired boron-dependent dose, there are other dose components which must be characterized to effectively predict the radiobiological effect. These studies have been done using two different boron agents and two reactor-based epithermal neutron sources (Brookhaven and the reactor in Petten, the Netherlands). The radiological effects of these various dose components are directly applicable, and are required to assess the BNCT boost from fast-neutron therapy.

These results, which have established the biological effects of the dose components, have been used to establish the starting point for the human clinical trials in progress at Brookhaven.

The Outlook

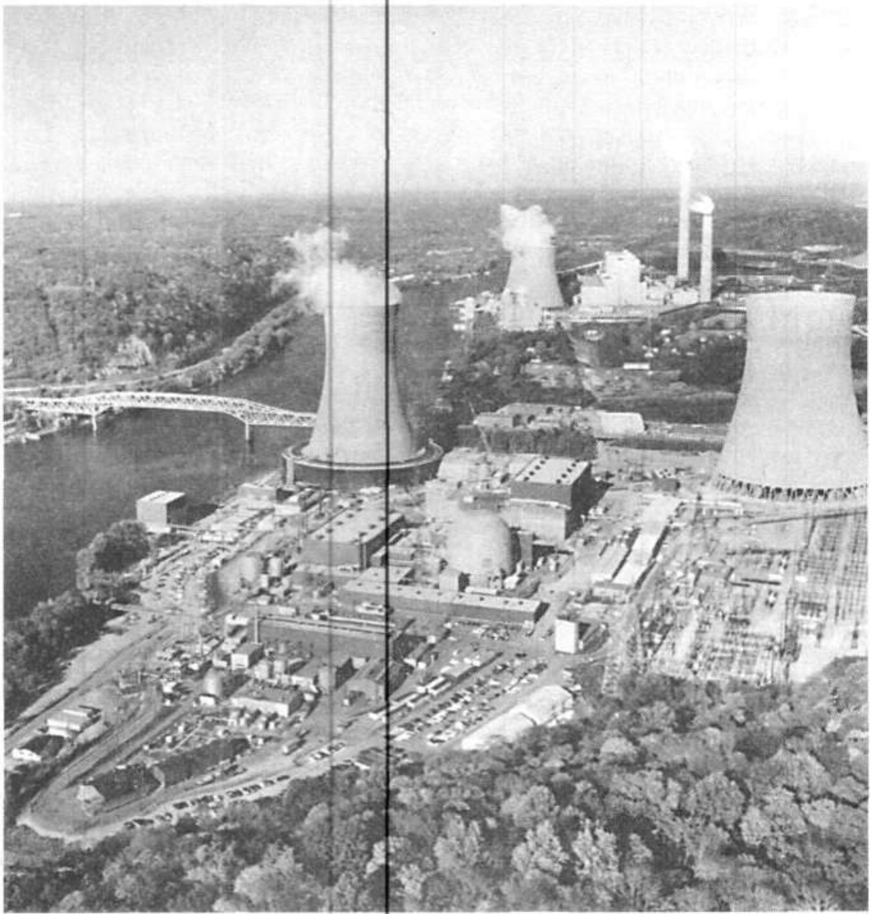
Recent advancements in boron-carrying pharmaceutical agents and improved epithermal neutron sources substantially improve the potential efficacy of BNCT. If a new boron delivery agent is used with neutrons of a quality equal to the Helsinki reactor, the effective radiation dose to tumors can be doubled, compared to present practice, which should have a very significant effect on tumor control.

Linden Blue is vice chairman of General Atomics in San Diego. He was formerly CEO of Beech Aircraft and general manager of Lear Jet, both in Wichita, Kansas.

Radiation Protection Policy: A Primer

by Dr. Theodore Rockwell

The current U.S. policy of a "linear no-threshold" approach to radiation damage has no science behind it.



U.S. DOE

Shippingport Station, the first commercial nuclear power plant, located in Pennsylvania. During its operation, the reactor was fueled with three different types of cores, the last one being a light water breeder core.

Every few months, the radiation protection establishment puts out another major study proclaiming yet again that the infamous linear no-threshold (LNT) model of radiation damage to the body is the best basis for radiation protection policy. There was "Health Effect of Exposure to Radon," known as BEIR-VI, issued in final form early February 1999 by the Committee on Health Risks of Exposure to Radon, Board on Radiation Effects Research of the National Research Council, and paid for by the Environmental Protection Agency.

Then there was "Evaluation of the Linear Non-Threshold Dose-Model Response," known as NCRP SC 1-6, issued in draft form November 1998 by the National Council on Radiation Protection and Measurements (NCRP), and paid for by the Nuclear Regulatory Commission (NRC). Each of these studies for three years supported a group of scientists well known for their adherence to the LNT.

Now, we learn that another three-year study is getting under way to produce BEIR-VII, another look at the LNT.

What's going on here? Methinks they do protest too much. In no other field of science is it considered necessary to repeatedly reaffirm the basic tenets of the prevailing theory. What is this LNT? Where did it come from? And what evidence and theory support it?

Current Radiation Policy

Current radiation policy is based on several key premises:

(1) The roughly *linear relationship* between radiation dose and health effects (for example, cancer), observed in atomic bomb survivors, is presumed to continue into the lower dose levels, where no effects are observed, all the way to zero dose. A single gamma ray is said to be capable of initiating a lethal cancer.

(2) The effect of *dose-rate is ignored;* no allowance is made for the body's proven healing capabilities. This is like saying that if 100 aspirin tablets are lethal when taken at one sitting, then taking one tablet a week would kill you after 100 weeks.

(3) The notion of *collective dose* is introduced. This says that individually trivial doses to an irradiated population can be added up to "predict" health effects, including deaths, in the population. This is like saying that if 100 people each take one aspirin, someone will die.

(4) *No account* is taken of the demonstrated *beneficial effects* of low-level radiation.

(5) *Radiation should be reduced* to "as low as reasonably achievable" with no attempt to define "reasonable." Courts and regulatory practice have already reduced this radiation goal to far below natural background radiation, with no end in sight.

This radiation policy was not derived from scientific theory and data; it was inherited as an administrative convenience for setting standards to protect against radiation at levels known to be potentially harmful. There was also the consideration that radiation levels too low to cause immediately detectable health effects might still be found to cause delayed effects, such as cancer or genetic damage, that would not show up until many years later.

However, we now have data on three generations of atomic bomb victims: *No heritable damage has been found, and the incidence of cancer is not observed at radiation doses below 10 to 100 rem* (0.1 to 1 Sv), depending on the type of cancer. Yet, the LNT is pushing us to regulate to ever-lower "permissible" radiation levels, not only below the natural background radiation, but even less than the *variations* in natural background from one region to another.

"Stop! You've had so much water over the past year, our regulations say you're going to drown!"

Let us examine the scientific case for the LNT and collective dose, as stated by its advocates in NCRP report 121, dated Nov. 30, 1995:

"Few experimental studies, and essentially *no human data*, can be said to prove or *even to provide direct support* for the concept of collective dose with its implicit uncertainties of non-threshold linearity and dose-rate independence with respect to risk. The *best* that can be said is that most studies do not provide quantitative data that, with statistical significance, contradict the concept of collective dose. Ultimately, confidence in the linear no-threshold dose-response relationship at low doses is based on our understanding of the basic mechanisms involved . . . It is *conceptually possible*, but with a vanishingly small probability, that any of these effects *could* result from the passage of a single charged particle, causing damage to DNA that *could* be expressed as a mutation or small deletion. It is a result *of this type of reasoning* that a linear non-threshold dose-response relationship *cannot be excluded* [emphasis added]."

If this is the best that can be said in defense of the LNT, then research yielding contradictory evidence should be encouraged and given very careful attention.

How Radiation Affects the Body

For most of the past few decades, radiation was called *health physics*, and was under the aegis of physicists and physicians. Their attention was on the probability of a cell being struck and damaged by an incoming ray or particle. It was assumed (but never demonstrated) that once a DNA molecule was hit, it was damaged and could lead to cancer. The more hits, the greater the chance of a cancer. Linear, right?

Recently, biologists have begun to look at the problem, and they found that for every DNA damaged by radiation there were literally millions of DNAs damaged by free radicals that were generated by the body's routine metabolism—day in, day out. To survive, the body is well prepared to prevent much of this damage, to repair what it cannot prevent, and to dispose of the cells not properly repaired. The comparatively few cells damaged by radiation are an insignificant burden to this magnificent defense system.

Even a lethal dose of radiation does not add significantly to the number of damaged DNAs. High-level radiation injures, not by damaging more cells but by degrading the defense system, which can then no longer keep up with the damage caused by routine metabolism. (Of course, high-level radiation also causes other damage; but the point here is that it is not the number of DNA molecules injured that matters.)

Evidence Contradicting the LNT

Discussions questioning the LNT often degenerate into arguments about the exact shape of the radiation/damage curve and the exact location of the threshold. For radiation protection purposes, there is a simple way around this dilemma: It's called *hormesis*. Hormesis is a biological term for the *beneficial* effect that small amounts of toxins have on the body. This is the basis for vaccination against disease, and for putting tiny amounts of selenium, boron, chromium, manganese, and other poisons in your vitamin pills.

These toxins, in small amounts, stimulate the body's defense mechanisms and actually *decrease* the number of damaged cells remaining. It has been known since 1896, a few months after Roentgen's discovery of X-rays, that radiation tends to work this way too. So, decreasing radiation below the natural background level (which is already less than one tenth of what it was when life first evolved) actually weakens the body's defenses and increases the chance of cancer and other illness.

We do not know all we would like to know about this process, but there is an enormous body of evidence at every level, from the molecule, to the cell, to living organisms, to clinical work with humans, showing that low-level radiation is not harmful, and can be beneficial. (See, for example, T.D. Luckey, "The Evidence for Radiation Hormesis" *21st Century*, Fall 1996, pp. 12-20.) This evidence makes clear that most of the money spent on radiation protection and regulation, on design and operation of waste-handling facilities, and on remediation of so-called "contaminated" land and facilities is being wasted.

Unfortunately, this evidence has been ignored, disparaged, mischaracterized, defunded, and left unreported, by radiation protection and research organizations who are invested in the radiation business, as well as by the antinuclear environmental groups that deal in irrational fear.

Radiation, Science & Health, Inc. (RSH),[1] an international not-for-profit organization of independent radiation experts (of which I am a founding director) is assembling this information into a large and growing Data Document, and is formally bringing the data to the attention of regulatory and policy bodies for consideration and action.

Status

The situation is now at a critical point. Through the efforts of RSH and others during the past three years, enough questions have been raised that both BEIR and NCRP have carried out three-year studies to evaluate the use of LNT for regulatory purposes. The BEIR study was limited to radon; a broader BEIR study on the general question of the suitability of LNT is just getting under way. The Health Physics Society, the American Nuclear Society, the Wingspread Conference, the French Academy of Sciences, and others have published statements questioning the use of LNT, but the policy remains virtually unchanged, and the wasteful and damaging practices that policy requires continue unabated.

Readers who believe this policy should be changed should make their views known to the Nuclear Regulatory Commission and the Environmental Protection Agency. As federal agencies, they should be required to demonstrate that their rules and regulations do more good than harm. As the world's premier radiation protection expert, Lauriston S. Taylor, wrote in 1980:

"Today, we know about all we need to know to adequately protect ourselves from ionizing radiation. Therefore, I find myself charged to ask: What is the problem and why is there one?. . . No one has been identifiably injured by radiation while working within the first numerical standards set by the NCRP and the ICRP in 1934. The theories about people being injured . . . must only be looked on as figments of the imagination. . . . I plead that we cease the seemingly endless procession of studies, congressional committees, and hearings on the problem of low-level ionizing radiation."

In the nearly 20 years since Dr. Taylor wrote these words, the "endless procession" has continued at an ever-increasing cost. Can those now profiting from this situation find the will to call a halt in time to save the nuclear industry from death by strangulation?

Theodore Rockwell (tedrock@cpcug.org) is a founding officer of the engineering firm MPR Associates, Inc., and a founding director of Radiation, Science, & Health, Inc. He is a Fellow of the American Nuclear Society and was Technical Director of Admiral Hyman Rickover's program to build the Nuclear Navy and the world's first commercial atomic power station at Shippingport, Penna.

Where to Comment on LNT

There are not many doors through which a person can walk to be heard on radiation policy. First, one can try to speak through one of the National Committee on Radiation Protection's affiliate organizations, of which the American Nuclear Society is one, and the Health Physics Society is another. But getting an agreed statement out of one of these organizations is almost as difficult as getting it out of NCRP.

The second doorway is less widely recognized, but more direct. The Nuclear Regulatory Commission (NRC) has an Advisory Committee on Nuclear Waste (ACNW), which it asks to comment on various issues, and this committee is currently receiving public comment on the NCRP document SC 1-6, concerning the use of the linear no-threshold model.

At the time that the NCRP report was being commissioned, July 10, 1996, this advisory committee wrote some pretty blunt words to the NRC, warning that the biased treatments of the past should not be repeated. It is not clear whether the full import of this warning was passed on to the NCRP. In any event, the current NCRP draft does, in fact, repeat the errors of its predecessors in not seriously considering the vast body of evidence that contradicts the LNT. The question remains whether the NRC will silently accept this report.

On March 23-24, 1999, the ACNW, chaired by John Garrick, met publicly to hear comments on NCRP SC 1-6. Unfortunately, none of the researchers who have generated the evidence contradicting the LNT were invited. James Muckerheide, Myron Pollycove, and this author, of Radiation, Science & Health, Inc., attended and had a chance to make some comments for the record. Raymond Johnson, president-elect of the Health Physics Society also commented, and Ted Quinn, President of the American Nuclear Society, made a brief statement to the committee on the importance that ANS attaches to this subject.

There were many good questions put to the LNT advocates, and the advisory committee is now in the process of drafting its report to the NRC commissioners. The final wording was to be worked out in a public meeting in mid-May, as this issue was going to press.

Notes

1. *Radiation, Science, & Health can be reached at* Box 843, Needham, Mass. 02194, Tel. (781) 449-2214, or E-mail to rad-sci-health@wpi.edu.

'Medical' Marijuana Is A Dangerous Fraud

by Colin Lowry

The media skewed coverage of the Institute of Medicine's recent report to promote pot legalization. The report actually documents marijuana's damage.

In the past few years, ballot initiatives permitting the medical use of marijuana, supposedly to treat chronically ill patients, have been approved in several states. These initiatives have been funded by the notorious international speculator George Soros, as a "Trojan Horse" for the legalization of illicit drugs. In response to this campaign, the Institute of Medicine (IOM) was commissioned to conduct a review of the scientific evidence "to assess the potential health benefits and risks of marijuana and its constituent cannabinoids," by the White House Office of National Drug Control Policy in January 1997.

The IOM report, released on March 17, 1999, reviews the biological effects of marijuana, documenting the damage it does to the brain's cognitive functions and motor coordination, its suppression of immune system function, and its damage to the reproductive system.[1]

The report also compares the effectiveness of marijuana to other drugs already in use to treat pain and nausea, finding it much less effective than currently prescribed drugs. In its conclusions, the IOM recommended against the use of smoked marijuana, citing the damage done by the tar and carcinogens to the lungs of users. It also concludes that the family of compounds known as cannabinoids, found in marijuana, may be useful for future drug development—the only conclusion to be played up, and distorted, by the media.

Damaging Effects of Cannabinoids

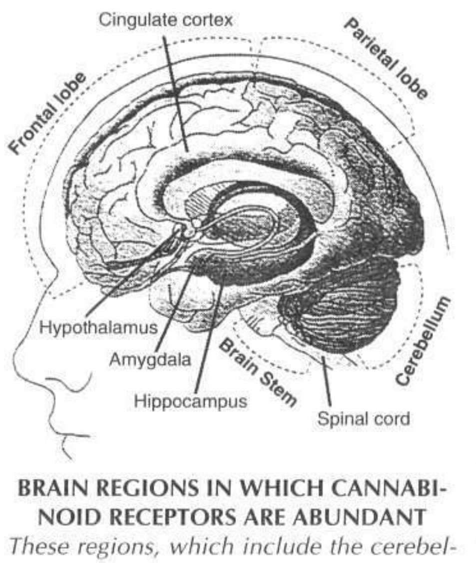
The substance of the IOM report documents the damaging effects of cannabinoids.

There are about 60 chemicals known as cannabinoids found in marijuana, of which delta-9-tetrahydrocannabinol, known as THC, is the most abundant of the psychoactive compounds. THC produces most of its effects in the brain and body by binding to specific receptors on the cell surface of neurons, or other cell types. One type of cannabinoid receptor was first found in the brain in 1990; a second type was found outside the brain in 1993. In 1992, a natural compound produced by the brain, called anandamide, was found to bind to the cannabinoid receptors, but its function remains mostly unknown. By also binding to these receptors, THC is interfering in a natural chemical signal pathway in the brain.[2]

The most consistent damage produced by chronic THC administration is loss of short-term memory. The area of the brain involved in short-term memory, and its transfer into long-term memory, is the hippocampus, which has a high concentration of cannabinoid receptors. Chronic marijuana users become tolerant of THC, and therefore have to smoke more and more to get the same "high." This causes permanent damage to the hippocampus, and may result in the inability to transfer information from short-term memory into long-term memory, a condition associated with Alzheimer's disease.

Studies of performance requiring auditory attention in people who have smoked only one marijuana cigarette show impaired performance, and this is associated with a substantial decrease in blood flow to the temporal lobe of the brain.

Cannabinoids also affect spatial memory, balance, and coordination. The cerebellum is largely responsible for coordinating motor control of the body, and this brain region also has a high concentration of cannabinoid receptors. A study of experienced airplane pilots showed that even 24 hours after the smoking of a single marijuana cigarette, their performance on flight-simulator tests was impaired.



BRAIN REGIONS IN WHICH CANNABINOID RECEPTORS ARE ABUNDANT

These regions, which include the cerebellum, hippocampus, and the parietal and frontal lobes of the cerebral cortex, are the most strongly affected by THC in marijuana. Learning, memory, balance, and the coordination of movement are all significantly damaged by the drug.

Source: Institute of Medicine

Stuart Lewis/EIRNS

Mega-speculator George Soros has bankrolled "medical" marijuana ballot initiatives across the country.

In addition, the regulation of hormones in the brain is altered by cannabinoids. Studies have shown that chronic THC administration in rats induces aging-like degenerative changes, which resemble the effects of stress exposure and elevated corticosteroid secretion.

Immunosuppression

One of the most serious consequences of the use of marijuana as a drug is the suppression of the immune system's function. Lymphocytes, including T-cells, which are responsible for fighting infection, are inhibited from proliferating by THC. B-cells, which produce antibodies that bind to foreign pathogens, are often inhibited from becoming active by THC, and even at very low doses, antibody production is reduced. THC also interferes with signals in the immune system that are mediated by cytokines. Studies in mice have shown that THC suppresses the cytokines that modulate the response to infection, and that the overall cytokine profile produced is abnormal.

Another detrimental effect is that THC from marijuana reduces the resistance to infection. In experiments with mice given THC, and then infected with sublethal doses of pneumonia-causing bacteria, most of these mice failed to fight the infection, and died of septic shock. However, control mice that were not exposed to THC fought off the infection, and became immune to repeated challenge by the bacteria.

Ludicrous Claims

Considering these dangerous consequences to human health from marijuana use, it is ludicrous to propose its use as a medicine. For example: One of the most ballyhooed proposed uses of marijuana is to treat nausea and weight loss experienced by AIDS patients. THC *is not very effective at treating nausea*, and the doses required for a modest effect are strongly hallucinogenic. Further, 90 percent of these AIDS patients are treated successfully with drugs already available. For the approximately 10 percent of AIDS patients who do not respond to standard treatments, synthetic THC, known as Marinol, can be legally prescribed in the United States.

However, THC is an immunosuppressant, so why would anyone want to give an AIDS patient, whose immune system is already gravely impaired, a drug that would decrease his or her resistance to infection?

Another of the proposed uses touted for marijuana is to treat nausea in cancer patients undergoing chemotherapy. The IOM report found that in clinical trials, THC provided only moderate control of nausea in 13 percent of the patients, as compared to drugs already available, which achieved complete control of nausea in almost 50 percent of the patients.

A profile of members of "medical use" cannabis buyers' clubs in California is included in the IOM report. Most of these "medical" users have used "recreational" drugs in the past, and more than *50 percent of these marijuana smokers* tested positive for cocaine or amphetamines.

The IOM report also shot down the anecdotal evidence that marijuana is effective at treating glaucoma. In fact, marijuana was found to be *ineffective* at lowering the pressure in the eye of glaucoma patients over a period of time longer than a few hours. The report also found marijuana to be only mildly capable of treating pain, being slightly less effective than codeine.

Although the report's conclusions eliminated smoked marijuana as effective at treating symptoms of diseases such as multiple sclerosis and Parkinson's disease, it did not adequately emphasize marijuana's damage to the cognitive functions of the brain. What the IOM report should have said, is that attempts to portray this damaging drug as a medicine, are nothing but propaganda for drug legalization.

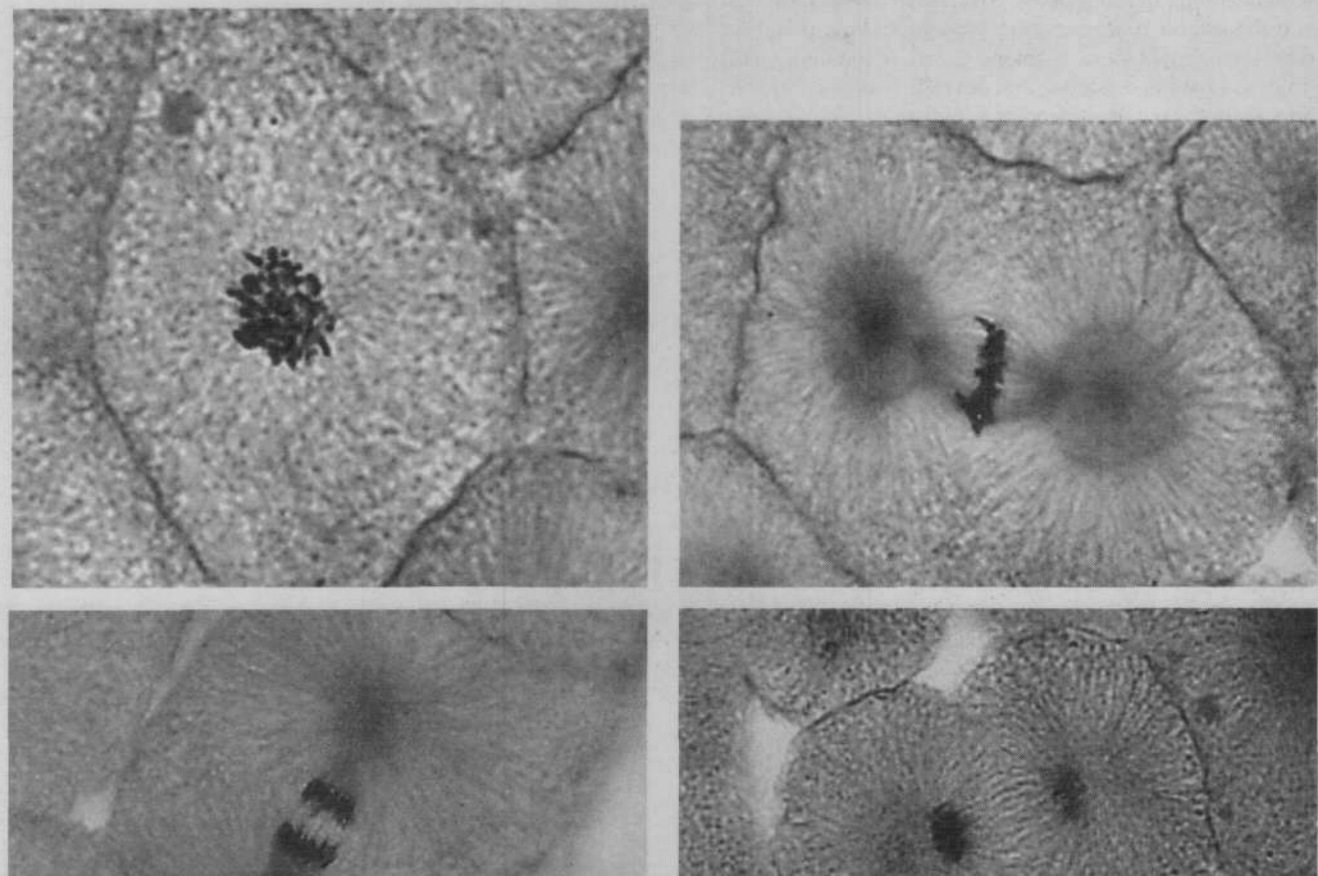
Notes

1. *Marijuana and Medicine: Assessing the Science Base,* Eds. Janet E. Joy, Stanley J. Watson, Jr., and John A. Benson, Jr., Institute of Medicine, Division of Neuroscience and Behavioral Health (Washington, D.C.: National Academy Press, March 1999).
   The full text of the report is available on line at http://www.nap.edu
2. For more details, see "The Medical Effects of Marijuana on the Brain," by Karen Steinherz and Thomas Vissing, *21st Century,* Winter 1997-1998, pp. 59-69.

The Scientific Basis Of the New Biological Paradigm

by Vladimir Voeikov, Ph.D.

The stable non-equilibrium that characterizes living processes belies the reductionist view of biology today, and leads the way to a real understanding of biological processes, beyond the Second Law of Thermodynamics.



Courtesy of Jeffrey Carmichael, University of North Dakota

Four views of animal mitosis prophase (top left), metaphase (top right), anaphase, (bottom left),and telophase (bottom right) in the blastula of whitefish. The condensed chromosomes are stained dark for better visibility.

The situation in biology on the eve of the new millennium reminds one of that of physics at the end of the last century. Twentieth-century biology has been based on the assumption that it is possible to reduce all vital manifestations to structures and processes governed by the laws of physics and chemistry, as established by studies of inorganic nature. This has allowed modern biology to achieve an impressive success in decoding the structure and discerning certain important properties of the material substrate of living things. However, the deeper our knowledge of the structural organization of biological objects, the more it is obvious that this basic assumption will not allow us to apprehend the laws determining the operation of the most specific vital processes.

An alternative theoretical and experimental foundation for the development of biological science, based on the postulate of the primacy of the phenomenon of life, was established in the first third of the 20th century, mainly by Russian scientists including E.S. Bauer, A.G. Gurwitsch, and A.L. Chizhevsky. It is hoped that the revival of their ideas, in light of the latest achievements of biology, biophysics, and biochemistry, will become an impetus for the development of biology towards an understanding of the specific laws of the phenomenon of life, and the establishment of a central Law of Organic Development, which will allow mankind to act in coherence with the objective laws of existence and development and, through this approach, to take possession of reality.

Is Biology Applied Physical Chemistry Or an Autonomous Science?

One reads in an old biology textbook: "Biology is the science of life in the widest sense of this term, or, to be more exact, the science of processes that proceed in living bodies."[1] It follows from this definition that the major task of biology is to unearth the laws of life. Such a formulation may seem too ambitious to many. In the opinion of the majority of researchers, there is not even a satisfactory definition of the phenomenon of life. In a recently published "Biological Encyclopedic Dictionary," biology is not considered to be an integral science. Rather, it is defined as a set of allied sciences dealing with separate manifestations of life.

The primary task of biology is defined as the pursuit of the discovery of regularities of manifestations of life. The task of understanding the essence of life is considered to be no more important than the task of perfecting biological systematics.[2] Such modesty in defining tasks for biology is not accidental. It reflects the long domination of the presumption that living organisms are no more than extremely complex machines.[3] If this is the case, it is enough to discover all the details of an organism's structure, and to study the processes taking place within it as an expression of the known laws of physics and chemistry. It is presumed that after decoding the exact composition and structural organization of living bodies, as well as the parameters and sequence of elementary processes combining to produce the known manifestations of life, one can put the knowledge obtained into proper order, and thereby understand the essence of life.

The development of biology in the 20th century has, in fact, demonstrated the fruitfulness of such an approach in many respects. The most intimate details of the structure of hereditary material (DNA) have been discovered; the structural features and properties of proteins participating in delicate chemical transformations have been revealed; sequences of stages of many complicated processes in living organisms and some elements of their regulation have become known. It has become possible to synthesize exact copies of complex biological polymers in a lab, such that the copies are able to execute the same functions as their natural originals.[4]

However, it is seldom mentioned that these copies can dis-

INTRODUCTION

What Western Scientists Can Learn From the Vernadsky-Gurwitsch-Bauer School

by Jonathan Tennenbaum

Readers of this article by Moscow University biologist Vladimir Voeikov may be astonished to learn, that a vast area of Soviet scientific research, which thrived for more than half a century and produced a great wealth of important experimental and theoretical discoveries, was almost completely ignored in the West until this day. In our best judgment, the reason for this lies not in secrecy (an extensive literature could be found in internationally circulated Soviet journals and monographs), but rather in the circumstance, that the fundamental, guiding concepts of this Soviet school of biology and biophysics—as typified by the work of Vladimir Vernadsky, Alexander Gurwitsch, and Ervin Bauer—ran counter to the main thrust of Western biology during most of this century.

While Western biology developed along ever-more strictly reductionist lines, looking at living processes essentially as *molecular machines,* the workers of this Soviet school recognized the distinction between living and non-living processes as *fundamental* and *irreducible.* According to Vernadsky, the existence and evolution of living processes on the Earth, and of human reason, as a fur-

Continued on page 20

play their full activity only after they have been inserted into living bodies in which the miraculous vital processes already occur. But, those who are convinced of the self-sufficiency of applying the physics and chemistry of inanimate nature to the understanding of the living state are not confused by these minor details. Typical are statements such as: "The external manifestations of life are the consequence of its internal structure, down to the molecular and atomic levels," and that ". . . as a result of the joint efforts of the experts on molecular biology, biochemistry, biophysics, and genetics, the hypothetical picture of the origin of life has largely been drawn. . . . [L]ife is not a mystery any more, but rather it is some kind of a puzzle, a code to be deciphered."[5]

The same approach is applied to a most significant biological process, the evolution of species. It is asserted that ". . . though many details require further investigation, it is already obvious that all the objective phenomena of natural history of life may be explained based on purely materialistic factors: selective multiplication in populations and causal genetic events. . . . [A] human being is a result of aimless and natural processes that never implied his emergence."[6]

Again, the current situation in biology reminds one of the situation in physics at the end of the last century, when many scientists believed that the main work had already been done, and that further progress would consist in the refinement of details, not in discovering something qualitatively new. For example, Max Planck's teacher, F. Jolly, insisted that: "Certainly, it is still possible to notice or to delete a speck of dust in this or another corner of the world, but the system is already firmly established, and theoretical physics approaches the same degree of perfection which geometry has possessed for many centuries already."[7]

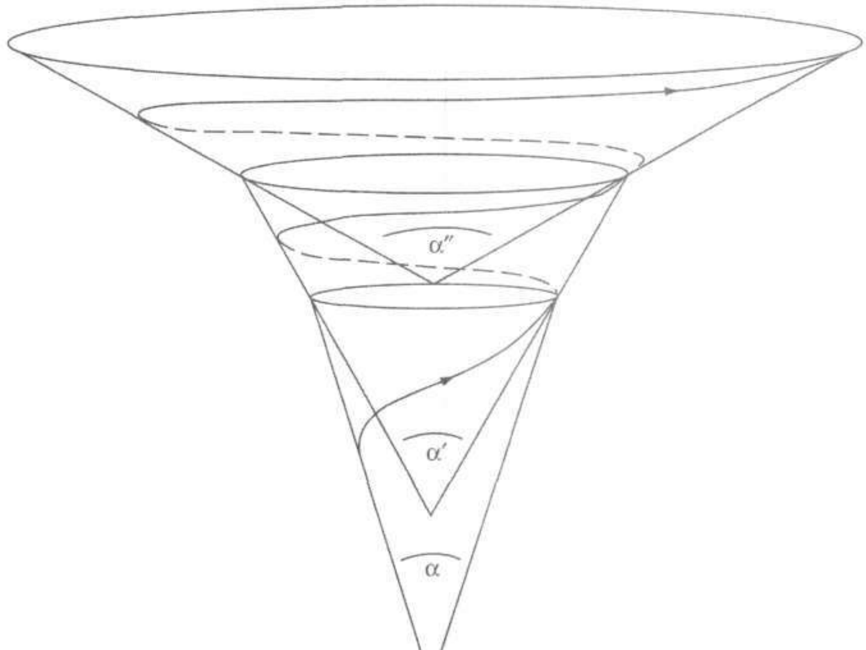
Irrespective of the achievements in biology, established on the basis of known laws of physics and chemistry, quite a few biologists are less than optimistic about the possibility of reaching an understanding of the laws of life based on this paradigm. They point to evidence showing that, in most cases, manifestations of vital activity cannot be predicted from a straightforward application of pure physical-chemical principles. In the opinion of Russian biogeochemist Vladimir

Continued from page 19

ther, axiomatically distinct process within the living domain, are no mere isolated or accidental phenomena, but constitute coherent expressions of a fundamental developmental characteristic of the Universe as a whole—a characteristic incompatible with the assumption of universal entropy.

The Vernadsky school also rejected Darwin's assumption, that the evolution of species arises from natural selection in a competitive struggle for survival. Rather, these scientists pointed to the unambiguously *directed* nature of the *transformations* of the biosphere as a whole (including its geological and geochemical substrate), accomplished through the activity of living organisms—transformations which represent *work done* by the aggregate of biological processes upon their environment, and which have led to an accelerating increase in the total energy throughput and overall physical-transformative power of the aggregate living process in the course of evolution.

That *directedness* of biological development, according to Vernadsky and his followers, is not merely the statistical end-result of a complex of essentially undirected individual



A geometrical representation of anti-entropic growth of a physical economy. The increase in capital-intensity of production during healthy economic development, is represented by the increasing apex angle of the variable conical surface upon which the growth spiral is developing. The continuation of the process leads to an increasing density of singularities, in which new families of technologies are introduced, producing the equivalent of a series of horn-shaped surfaces like the one shown. As Vernadsky and others demonstrated, biological evolution has very similar characteristics.

Vernadsky (1863-1945), there is "a radical distinction between living and dead things, and this distinction must be based on some fundamental difference in the matter or energy, located inside living organisms, in comparison to that found by the methods of physics and chemistry in inanimate, lifeless matter. Or rather, this distinction points to the insufficiency of our usual notions of matter and energy, deduced from studies of inanimate nature, for the explanation of all processes of life."[8]

Undoubtedly, there are some general features specific to all living systems, and the processes within them, that allow us almost unmistakably to distinguish between life and death. Many great thinkers of the past tried to formulate this basic distinction, but only a few have risked asserting the *primacy of life* as the major postulate of biology. Starting from this postulate, the Russian scientist Ervin Simonovich Bauer (1900-1937?) constructed the axiomatic basis for theoretical biology, to stand as an autonomous science. Alexander Gavrilovich Gurwitsch (1874-1954) put forward the theory of a specific biological field as the solution to one of the major problems of biology, the problem of morphogenesis. Gurwitsch presented vast experimental material confirming the main principles of theoretical biology. Alexander Leonidovich Chizhevsky (1897-1964) discovered the fundamental dependence of vital processes on subtle impulses coming from space. Before proceeding to an analysis of their work, let us take up the question of whether the postulation of primary biological principles is indeed necessary.[9,12]

Activity and Directness of Vital Manifestations

Among the manifestations of life are metabolism, reactivity, reproduction, growth, and development. It is possible to find analogies in the properties of inanimate bodies or phenomena, observable in inanimate nature for each of these. Take, for example, continuous metabolic flow of matter and energy through a system—the continuous replacement of its material composition. One can point to numerous processes in the inorganic realm that are accompanied or stipulated by exchange of matter. However, "metabolism" in individual non-living systems generally results in their destruction, whereas in living

events; rather, it must reflect a definite physical principle, which is active at every point in the process. This means that the *anti-entropic,* directed characteristic of the biosphere as a whole must also be expressed at the level of the *infinitely small,* as a distinctly different type of space-time *curvature,* compared with that prevailing in non-living processes. Vernadsky himself proposed that the work of the mathematician and physicist Bernhard Riemann, on generalized curvature of manifolds, be used as a guide for experimental investigations of biophysics.

Vernadsky went a step further: In the course of documented history, the human race, through the gradual technological improvement and expansion of its social-productive activity, has increased its aggregate power over Nature at an accelerating rate, to the point of becoming the dominating force within the biosphere. The improvements in production, and analogous improvements in social organization, which have permitted that growth in physical power, derive from the creative powers of individual human minds to make scientific and analogous discoveries of principle, and apply them to human social practice. For this reason, Vernadsky spoke of the emergence of the *noosphere*—a biosphere evolving under the conscious direction of human reason—and of human reason itself as a *planetary (and in the future, interplanetary) force.*

LaRouche's Contribution

Vernadsky's conclusions have been greatly deepened and rendered more rigorous by the discoveries of Lyndon LaRouche in physical economy and, particularly, through LaRouche's elaboration of the concept of the *rate of increase of potential relative population density* as the fundamental yardstick for the *anti-entropic* development of economic processes.[1] The relationship between LaRouche's and Vernadsky's work, and the historical basis for that relationship, was noted by LaRouche many years ago. In the meantime, however, more points of contact have emerged. The Summer and Fall 1998 issues of *21st Century* feature a two-part series dealing with the work of the great Russian biologist Alexander Gurwitsch, whose concept of the *biological field* is closely related to the deeper side of LaRouche's work, namely, on the nature of human creative mental processes themselves.[2]

During a discussion among this author, Prof. Voeikov, and another Russian colleague some time ago, we were all struck with the similarities between LaRouche's conception of physical economy, and the work of Ervin Bauer, a somewhat lesser-known Soviet biologist connected with the Vernadsky-Gurwitsch school. Bauer did not directly address economic questions, but his approach to living processes from the standpoint of *work* performed upon the environment, in such a way as to increase the future viability and work-potential of the living process, immediately parallels the approach of physical economy, and illustrates the fundamental importance of physical-economic concepts for biology as a whole.

Unfortunately, there is a great dearth of literature in the West on Bauer and his work. That is one reason that we are publishing this article by Prof. Voeikov, which, in addition to giving an introduction to the work of Bauer and his relationship to Vernadsky, Gurwitsch, and others, contains many other interesting and important ideas.

We hope that our continuing publications on the indicated subjects will stimulate fruitful discussion on some extraordinary ideas and results, which, in the West, at least, have not yet received the attention they deserve.

Jonathan Tennenbaum heads the Fusion Energy Foundation in Europe and is a scientific adviser to the Schiller Institute. He is also a member of the scientific advisory board of 21st Century.

Notes

1. A recent presentation of LaRouche's economic views can be found in his article "The Economics 'I.Q.' Test," *Executive Intelligence Review,* May 14, 1999.
2. *Alexander Gurwitsch and the Concept of the Biological Field,* by Michael Lipkind (a student of Gurwitsch), Summer 1998 (Part 1) and Fall 1998 (Part 2).

Bauer as a young man, courtesy of Vladimir Voeikov

Ervin S. Bauer (1900-1937?) was born in the Austro-Hungarian Empire, in the town of Leche, now Lechova, Czech Republic. He graduated from the Medical Faculty of Göttingen University, and worked in Hungary as a medical doctor. He actively participated in the Hungarian communist revolution in 1919, and after its failure, Bauer had to emigrate first to Austria, then Germany, then Czechoslovakia. During this period, he published his first book on the problems of theoretical biology, Grundprinzen der Reinen Naturwissenschaftetlichen Biologie.

In 1925, he was invited to continue his scientific work in Soviet Russia, and this was the most creative period in his life. In 1934, he was appointed as the head of the Department of General and Theoretical Biology of the All-Union Institute for Experimental Medicine in Leningrad, where Alexander Gurwitsch also worked as the head of the Mitogenetic Laboratory. Bauer's major book, Theoretical Biology, *was published in 1935.*

Bauer was arrested in 1937 by the NKVD, together with his wife, Stefania Szilard, a relative of the physicist Leo Szilard. The exact time of his death (or execution) is unknown. His name and work were almost never mentioned in scientific literature until 1964. The only exception was Alexander Gurwitsch. Irrespective of his rather cold relations with Bauer, Gurwitsch was never afraid to mention Bauer's name and stress his priority in the conception of the "Stable Non-Equilibrium Principle" in his own books and papers. Although more people now know the name of Ervin Bauer, only a few understand his real impact on theoretical biology, partly because his book Theoretical Biology, *printed in 1935 in 5,200 copies, is now a rarity.*

systems it is a necessary (though not a sufficient) condition for preservation of the living state.

In addition the main feature of metabolism in living systems is that they actively consume matter and energy from the environment, whereas an inanimate object is a passive participant in a similar process. The majority of "metabolic" processes in the inorganic realm are directed by the action of external forces, or occur after energy has been pumped into the system. After the termination of action by the external force, these processes proceed only by inertia. The living process, by contrast is carried out as though spontaneously—although living phenomena are always triggered by external stimuli. Such impulses (irritations, "prompting") may rarely be regarded as an external force. As a rule, the amount of energy released (made free) in response to such an impulse greatly exceeds the energy of the impulse.

Similar phenomena may be observed as well in inanimate nature. A small spark gives birth to a fire. But fire is formless in comparison with a living system. Besides, unlike the latter, it irreversibly destroys those structures which it touches, and never creates new ones. Fire "dies" out as soon as the fuel is exhausted. A living system seldom "burns out" the fuel it extracted from the environment. Rather, it builds up its own energy stocks in a specific form in order to prolong its existence. However, no individual organism can live forever. Death, the transition into a "natural" state that agrees with the known laws of physics and chemistry, comes inevitably.

Having recognized this obvious fact, one may sit back and study the development of an individual organism as merely a step on the way from an animate being to a dead object. However, any individual, whether it be an animal, a plant, or a microorganism, may be envisaged as an element in a series of self-reproducing individuals. The uniqueness of self-reproduction of living systems is seen in the fact that a newborn system must first pass through a stage of development and growth. (Some biologists—for example, the outstanding plant physiologist D.A. Sabinin—do not consider growth, or the increase of an organism's mass, as an independent vital manifestation, but rather as the expression of development.[13])

Development is the most unique feature of living systems. One of its clearest manifestations is the continuous (or, from another point of view, step-wise) emergence *de novo* of processes and associated structures. These emergent processes and structures may be envisaged as an increase in the degree of differentiation of the parts of the same living system, owing to which the stability of a system is enhanced, despite the adverse factors of environment, while at the same time, its ability to interact with the environment grows. The sequence of self-reproduction may itself be regarded as some super-organism that exists incomparably longer than the individual organisms which make it up. The stages of development take up a considerable portion of its "lifespan."

Finally, if one accepts the formulation of Vernadsky that "phenomena of life and of inorganic nature, taken from a geological (that is, a planetary point of view), are manifestations of a uniform process," it appears that the process of development—allegedly "impossible" from the point of view of the physics and chemistry of inanimate nature—the process of transformation from the lower to the higher, from uniform and incoherent to differentiated but indivisible, is the main natural process. If this is true, then, perhaps the "Laws of Nature" commonly taught in school, are just particular cases, while the main law, the law of the steady increase of organization, is not yet comprehended by us.

It turns out that the living state is the unity of two opposites. On the one hand, any living system is characterized by a specific structure, form, and geometrical pattern. That is what makes it possible to distinguish different species and even individuals, although the form of a living system is regularly changing during its life cycle and even the closest relatives are never identical in their morphology. A living system, on the other hand, is a continuous process or, rather, a combination of parallel and alternate processes. Conservation of a living system's structure, components of which are continuously replaced with new ones, is possible only through the strict coordination and interaction of life processes.

Looked at another way, all life processes may be envisaged as the regular formation and disruption of links between more or less stable structures. We may define these links as messages, and their contents as information. Energy release and/or consumption is the necessary condition for the installation or disruption of any link, as well as of any metabolic process. From this point of view, the reactivity of a living system is a burst of information-energy exchange within it, in response to stimulation by an external factor, which may in some cases be as small as a single quantum of energy. Reactivity implies the inherent activity of a living system.

Bauer's Theory: Structure-Energy Specificity of Living Systems

It is possible in many cases to reduce a particular vital manifestation to a physical-chemical process. However, it appears impossible to deduce the unity of living processes—their holistic, active, and directed structured process—from the physics and chemistry of inanimate nature. The most basic difficulties arise when one attempts to explain those features displayed in the process of development of living systems. When, on the eve of the 20th century, physicists realized that it was impossible to deduce the existence of the quantum of action and the final divisibility of matter from classical mechanics, Niels Bohr resolved the problem by formulating a set of new postulates. On this foundation, a large edifice of quantum physics is now constructed. It turned out also that the principles of classical mechanics follow from quantum physics and not vice versa.

A similar attempt in biology to unite and express in the form of laws the basic features peculiar to all living systems without exception, was undertaken by E. Bauer.[14] His first principle ("the Principle of Stable Non-equilibrium") is formulated as follows: "No living system is ever at equilibrium. It continuously performs work against equilibrium, demanded by the physical and chemical laws appropriate to the actual external conditions." Thus Bauer asserts that a living system already appears in a non-equilibrium state from its first moment of existence, as a birthright, so to speak, inherited from another living, and hence already non-equilibrium, system.

Another feature is equally important: all activity performed by a living system is aimed at avoiding the slide into equilibrium with its environment. As any living system is out of balance with its environment, from the first instant of its individual existence, all its essential structural elements must also exist in a state of disequilibrium with the immediate environment. If so, the free energy that a living system uses to perform work against sliding into equilibrium is free energy from its non-equilibrium structures, *structural energy* in Bauer's terminology. Such a form of energy differs fundamentally from the forms of energy encountered in inanimate nature. Non-equilibrium, then, should be displayed at all levels of a living system, beginning at the molecular one. It includes the sustaining of chemical gradients, electrical gradients across membranes, the non-equilibrium state of its macroscopic structures, and so on. Most important, it includes the non-equilibrium of the essential molecular components of living cells, a point to be discussed in detail below.

As work is performed against equilibrium, free energy is consumed, and each element of a living system performing the job, inevitably slides towards equilibrium, finally turning into ordinary lifeless matter. In order to preserve the non-equilibrium state, a living system continuously repairs or substitutes its exhausted structural elements. Energy is needed to carry out this work, and according to the Principle of Stable

Vladimir Vernadsky (1863-1945)

Non-equilibrium, this energy comes from certain inherent non-equilibrium structures in a living system. Such work, aimed at keeping an individual living system from sliding towards equilibrium, was defined by Bauer as *internal work*.

No matter how efficiently internal work is performed, a living system gradually loses its free energy and the matter "charged" with it, and needs to replace them with matter and energy (chemical energy of food, energy of light, and so on) consumed from its environment. It must seek resources in its environment, separate the useful structure-energy substrates from the useless ones, and assimilate the former into its own energy-charged *structural elements. All these procedures re*quire the performance of work by a living system. Unlike the *internal work*, this kind of work is performed on a living system's environment, and it should be defined as *external work*.

The external work inevitably enters into contradiction with the internal work. Both share a common source of energy, the structural energy of the elements of the living system. During the performance of external work, a living system loses its structural energy, thus sliding toward equilibrium. Reduction of its non-equilibrium resulting from its own efforts, contradicts the Principle of Stable Non-equilibrium. Insofar as a living system cannot violate the principle of its existence, it may perform external work only by infringing on the non-equilibrium of its structures, under the influence of external impulses. External influences, *irritations*, infringing to a certain extent on the non-equilibrium of a living system, have the effect that the energy freed is spent to perform external work rather than internal work. This provides for the replacement of matter that has lost its non-equilibrium state by new structures, built by the living system in an already excited state, and providing their ability to perform work.

The contradiction between the internal and the external work follows from the Principle of Stable Non-equilibrium, but it is unresolved within the framework of the principle. The only reliable solution to the problem is the increase of the general stock of energy available to the system for performing both external and internal work. Therefore, the process directed toward an increase in the general stock of free energy must begin from the moment of birth of a living system. However, such a process can reach its goal only if the external work more and more dominates over the internal. Thus, only living systems exhibit a directed "structured process," the overall vector of which points to an increase in the general stock of free energy of the system, or, in other words, its stable non-equilibrium. Bauer has defined this dynamic principle: the *Principle of External Work Increase As the Historical Trend.* By the word "trend," he emphasized that the principle is displayed as the main tendency of the process, while significant deviations from it may be observed in its course.

Thus, Bauer has formulated the general laws of motion of living objects, inherent only in them. The Principle of Stable Non-equilibrium asserts that the activity of a system directed to the preservation of the non-equilibrium state is the necessary (but not sufficient) condition for the recognition of a given system as living. The Principle of External Work Increase As the Historical Trend is a sufficient condition for preserving its viability. The opportunity for a living system to proceed in this direction is provided by a sufficient supply of power and material resources in its environment, and its openness to external stimuli ("irritations, prompts") that initiate its interaction with the environment.

All the dynamic vital manifestations—metabolism, self-reproduction, and multiplication, development as an increase in the state of stable non-equilibrium—follow from the principles formulated by Bauer. But these laws say nothing of another fundamental characteristic of living systems: the process of development seen as the acquisition of a specific form, morphogenesis, or, in other words, heredity and variability, and the means of their realization. An attempt to deduce laws governing this process in living systems was made by A. Gurwitsch in his theory of the biological field. Before we turn to his theory, however, we shall consider some experimental confirmations of Bauer's principles and major consequences that follow from them.

Courtesy of L. Beloussov

Alexander Gavrilovich Gurwitsch (1874-1954)

A Living System Is As Hot As the Sun

The non-equilibrium of a living system should be displayed at all levels of its organization. So, at the temperatures characteristic of the existence of life, the maximally non-equilibrium state of molecules is the state of their maximum electronic excitation. Transition of an excited molecule to a ground state is accompanied by photon (light) emission. In 1923, Gurwitsch discovered that living organisms emit photons in the ultraviolet (UV) range of the spectrum (very high energy photons).[15] Intensive studies in many laboratories subsequently showed that nearly all cells, tissues, and organisms are capable of emitting such radiation, and that UV photons are a prerequisite factor for induction of cellular division (mitosis).[16-18] Gurwitsch thus defined such emission as mitogenetic radiation.

The intensity of spontaneous mitogenetic radiation is extremely low.[19] In addition to this type of radiation, however, in response to multiple external factors, all living systems emit a considerably more intense photon flux in the UV as well as in the visible part of the spectrum. These factors include external irradiation, heating, cooling, mechanical stress, influences of chemical compounds, and so on. Gurwitsch defined radiation emission induced by such factors as *degradative radiation.*[17]

The reaction of living systems to a variety of external impulses by emitting a flare of radiation suggests the transition of ensembles of excited molecules from a non-equilibrium towards an equilibrium state. The phenomenon observed may be defined in modern terms as light amplification by stimulated emission of radiation—what we know as LASER. As part of this radiation possesses mitogenetic properties, and in order to distinguish it from well-known technical lasers, we may define such radiation as mitogenetic-laser. The spectrum of mitogenetic-laser is comparable to the spectrum of solar light:[20] Therefore, one may say in a certain sense, that the "temperature" of excited ensembles of molecules in living cells corresponds to the temperature of the Sun.

It follows from the First Principle of Bauer, that the free energy of a living system is the energy of its excited structures, and it follows from the Second Principle that, in the course of its development, the total stock of free energy in a living system increases. These consequences are confirmed by the analysis of the changes in ultra-weak radiation during the development of a living system. In the course of embryonic development, the intensity of spontaneous radiation decreases, while that of mitogenetic-laser significantly increases.[21, 22] That means, first, that during the development of the interconnectedness of the newly emerging parts of the system, its overall coherency increases, so that its energy losses as a result of radiation emission decrease. Second, the developmental process includes saturation of the system with the most "expensive" energy—the energy of electron-excited states.

Many opponents of Gurwitsch and Bauer have claimed that the Second Principle of Bauer, according to which living systems are capable of self-organization as a result of their ability to concentrate energy actively drawn from the environment, is impossible, because such a process contradicts the Second Law of Thermodynamics. However, it is hard to deny that during any living system's development, its non-equilibrium is enhanced and its stock of free energy increases. Currently, the thermodynamics of open systems and "synergetic" models developed mainly by the Nobel Prize Laureate Ilya Prigogine, is employed to explain this phenomenon.[23, 24]

Prigogine demonstrated that if the energy flow is maintained across a certain open system (a system that may exchange matter and energy with its environment), it may be drawn away from equilibrium with its environment. The system becomes structured; it accumulates free energy, and its entropy is decreased, but at the expense of entropy increase somewhere where the source of energy flow is discharging.

It seems to many scientists that the thermodynamics of open systems explains the process of "self-organization" in living systems sufficiently well. However, the similarity between "self-organization" occurring in "open," inanimate systems, and the development of living systems, is readily apparent. "Self-organization" in the former takes place as a result of energy flux through the system. It passively gets matter and energy from its environment. A living system, in contrast, actively extracts matter and energy from its environment, expending its own resources to obtain them, and to transform this energy-matter into the more "expensive" energy of excitation of its own structures. Generally speaking, the phenomena of steady increase of free energy stock and of "self-organization" are observed in special physical-chemical systems which do not belong to the category usually described in thermodynamics of open systems. These are the systems where branched chain processes occur.

The Branched Chain Process of Life

Let us return to the comparison of life and fire. A flame, which under specific conditions can be cold, is an example of the widespread natural phenomenon of branched chain processes, discovered by the Nobel Prize Laureates N.N. Semyonov[25] and C. Hinshelwood.[26] When a certain (sometimes extremely weak) impulse initiates branched chain processes in some medium that seems to be rather inert, active centers arise and begin to multiply in it. But the rate of multiplication of areas of activity is equalled, sooner or later, by the rate of their loss. Then the latter process begins to dominate, and as the whole process comes to its end, the final result is the same as for any other chemical and physical process proceeding in closed systems: absolute reduction of free energy, and growth of entropy in the system.

However, the essence of a branched chain process is manifested in its dynamics, rather than in its overall balance. At the stage of multiplication of active centers and chain branching, a spontaneous growth of free energy takes place. A dynamic orderliness of the system occurs, accompanied by the concentration of significant energy potentials in certain of its domains. If, at this stage, the system comes into interaction with another, seemingly resting one, a similar process can be initiated in the second system. Considering this property of branched chain processes, Hinshelwood once noted: ". . . It is very possible and even is rather probable, that from the very instant of life's emergence on the Earth, a giant branching reaction has taken place."[27] Semyonov also never doubted the important role of the branched chain reaction mechanism in living processes.[28] However, until now, only a negative role was ascribed to branched chain processes in living systems.[29] Branched chain processes underlie pathologies related to free radical reactions of cell membrane destruction. Malignant growth can also be described as an "unrestricted" branched chain process.[30]

Already in the 1930s, Gurwitsch understood that branched chain processes have a fundamental importance for living processes.[31] For example, it is impossible to explain the stimulation by a few photons of multiple cell divisions in a cell population without invoking a cascade mechanism of tremendous capacity, and, in fact, it has been demonstrated that the mechanism of mitogenesis is related to photon "multiplication." After a competent cell absorbs an external photon, a branched chain process is initiated in it. This is followed by the emission of multiple new photons, and this secondary radiation then stimulates division of many other cells. However, if the intensity of external radiation exceeds some optimum, inhibition of cell division rather than stimulation is observed. That is, the same factor, depending on its intensity, can cause opposite effects in living systems. Finally, if branched chain processes in a living system get out of control, the pathological phenomena mentioned above may take place.

Gurwitsch discovered that similar branched chain processes can be initiated in a simple chemical system-an aqueous amino acid solution. Irradiation of such a solution with just a few UV photons induces a process that is followed by continuous emission of UV photons from this system. Gurwitsch suggested that this is a branched chain process.

Recently we have studied the Gurwitsch reaction on a new experimental basis, and confirmed his suggestion of a branched-chain mechanism in these reactions.[32-34] Specifically, the reaction induced in the amino acid solution proceeds according to the mechanism of chain reaction with delayed chain branching. It resembles the well-known branched chain reactions of the explosive type, although it differs from the latter in some significant properties. It was discovered that clear self-organization occurs in the reaction system. The reaction displays features of inertia (memory of a system) and feedback. We also found that there are elements of autoregulation of the intensity of the reaction rate.

This very simple—at first sight—but highly peculiar system, manifests a certain expediency as well. A polymer-like substance emerging in the reaction system is stable and can even "multiply" to some extent, but only in the reaction system. After isolation, it rapidly degrades into monomers.[35] Apparently, it can maintain its existence because of work it performs in the reaction system: This substance increases free energy of the system and later maintains it at a certain level, gaining energy through catalysis of the oxidation of amino acid molecules.

It seems that the most essential features observed in our experimental self-organizing system are common to all other developmental processes. Such processes are initiated by very weak external impulses. This is followed by a net increase in the free energy of system, equivalent to an increase in its non-equilibrium. In addition, structural self-organization takes place: The number of polymer chains and their length increase to a certain extent, and new compounds participating in the process arise.

Courtesy of Vladimir Voeikov

The author in his laboratory, standing near the device for single photon counting.

However, there are important differences between branched chain processes occurring in inanimate and in living systems. First, the free energy of an inanimate experimental system increases mostly (if not exclusively) because of energy that had been stored in the chemical bonds of amino acids present in the reaction system from the very beginning, which is released in the course of their oxidation by oxygen passively diffusing into the system. Second, after the process in the test-tube comes to a stationary stage, it begins to fade, and can be revived only if we transfer a small part of the active reaction mixture into a test-tube with a fresh portion of substrate. A living system, in contrast, actively extracts energy-matter from its environment, and is also capable of creating new living systems. Thus, the reaction in a test-tube proceeds according to the First Principle of Bauer, but it does not implement his Second Principle. In order to implement it there must be an open system, but of a very specific sort: Its openness must be intermittent. In other words, it has to be mostly closed at the stage of active sites multiplication; it has to become opened, when for some specific reasons discussed below, the rate of multiplication of active sites comes to equal the rate of their extinction.

Chain Reactions of Reactive Oxygen Species In the Regulation of Living Functions

It is important to specify here, that branched chain reactions studied by Semyonov and Hinshelwood, mostly in the gaseous phase, may be considered only as prototypes for those reactions that proceed in an aqueous organic medium. There, only the so-called chain reactions with delayed branching may take place. The latter start as linear chain reactions, but during the major chain propagation, intermediate metastable products emerge. Much lower energy of activation is needed to produce new active centers from these products than from the initial substances. Thus, even if the "parent" chain is eliminated, the new chains arise in the system, provided that enough energy for the activation of these metastable products is available.

Reactions of reactive oxygen species (ROS) are up to 10-fold more exergonic (liberating energy) than ordinary biochemical reactions. ROS interact non-specifically with many organic molecules. Because of these properties, ROS are extremely strong oxidants and are considered to be the universal pathogens in the contemporary biochemistry paradigm. Their generation in living systems is looked upon as a grievous, though inevitable, price for aerobic respiration, that has emerged in the course of the evolutionary process consequent to the appearance of atmospheric oxygen—the byproduct of plant photosynthetic activity.

However, this concept ignores much hard evidence showing that ROS are absolutely necessary for normal vital activity. If air is deficient of superoxide anions (Chizhevsky's "negative air ions"), human beings and animals become sick and can even die. On the other hand, more than 10 to 15 percent, and under special conditions up to 30 percent, of oxygen consumed by animals goes to ROS production. ROS are continuously generated in the body by ubiquitous specialized enzymes, by enzymes performing other primary functions; they are also generated non-enzymatically. Thus, ROS should play rather important physiological functions.

Living cells are known to react to external stimuli in one of the following ways: They either perform their specialized function, or change their specialization (differentiate or dedifferentiate), or proceed into the mitotic cycle, or, finally, proceed into the so-called "programmed cell death"—apoptosis. It turns out, that in most cases, ROS determine the outcome of cell reactions upon specific extracellular biomolecular regulators. In addition, ROS themselves may imitate the action of certain hormones, neurotransmitters, and cytokines upon particular cells. Biomolecular regulators may, in their turn, modulate ROS production by the cells. Thus, ROS may be looked upon as universal information messengers.

However, if ROS are devoid of the specificity attributed to biomolecular regulators, how can they provide a precise regulation of cellular functions? Although a considerable part of consumed oxygen is used in the organism for ROS production, the average levels of free radicals and other ROS in cells and extracellular fluids are extremely low. The so-called antioxidants of enzymatic and of other nature, cause a very high rate of their recombination and transformation into other compounds. Thus, very slight variations in the rates of ROS production and/or consumption, may result in drastic spikes and oscillations of their immediate levels.

It should be stressed that the processes of ROS metabolism, and in particular the reactions of their recombination, are accompanied by the generation of electron excited states. Ours and other authors' results suggest that as a result of cytoplasmic organization, the energy of electron excitation is unlikely to dissipate into heat. Rather, it may accumulate in molecular and supramolecular ensembles, and redistribute among them by radiative and radiation-less routes, providing intracellular and intercellular cooperation. How can this be done?

It is more and more recognized that biological reactions proceed as nonlinear oscillatory processes. In particular, as we and others have shown, the processes involving ROS are oscillatory, as a rule. We speculate that the mechanisms of biological action of ROS are dependent upon the structure of the processes in which they participate, rather than upon the mean concentrations of these particles. By the "structure of the processes," we imply the frequency-amplitude patterns of the reactions of ROS recombination and their interactions with other partners, taking into consideration that these processes supply energy of activation for the numerous specific biochemical reactions.

Periodic as well as nonlinear oscillations emerge in the processes of ROS metabolism, but they decay without repriming by periodic external signals. Hence, for effective ROS production, the organism should be "sparked" from the outside. "Sparks" may come in the form of air- or hydro-ions (external O_2^- or O_3), or by virtue of ROS generation in its aqueous medium by high energy photons (UV- and lower shortwave range).

Oscillations that arise in the course of ROS metabolism in the organism, and that in their turn determine and/or modulate the rhythms of biochemical and physiological processes, are more or less dependent upon certain external oscillators, in particular, upon oscillations of external electromagnetic and magnetic fields. ROS reactions may be very sensitive to their influences, because they are intrinsically the processes of electron transfer in electron-excited media. Such processes, as it follows from the current concepts of the physics of nonlinear autostochastic systems, are highly sensitive to weak resonance interactions.

Let us consider now how ROS can regulate biological functions at the level of the whole organism. It is well known that blood neutrophils can efficiently generate ROS, which, in this case, are considered to be used for killing viruses and bacteria. However, it turns out that lymphocytes and thrombocytes, that do not participate in direct elimination of microbes, also produce ROS. Fibroblasts, endothelial, and smooth muscle cells also possess highly active ROS-generating enzymes. ROS production by connective tissue, to which both blood and "ordinary" connective tissues belong, is of particular interest in the light of the presumed energy-informational role played by ROS metabolism. ROS are generated not only by cellular elements of connective tissues, but also by extracellular proteins (although in the latter case at a much lower rate). Plasma proteins and collagen become sources of ROS as a result of their glycosilation (Maillard reaction).

It should be stressed that all the collagens and many plasma proteins have fibril helix structure and are able in principle to transfer electromagnetic-waves for long distances. It is interesting to speculate that, in addition to their structural function, extracellular connective tissue elements perform another important role in all the organisms: the role of channels for information transfer that join together all the tissues and organs, and that are also exposed to the periphery (say, in the form of acupuncture points). Cellular elements of connective tissues play in this case the role of re-translators, decoders, and amplifiers of the incoming signals. Needless to say, all living things possess connective tissues or their analogs, even if they are devoid of blood and nervous systems.

Death As a By-product of Life

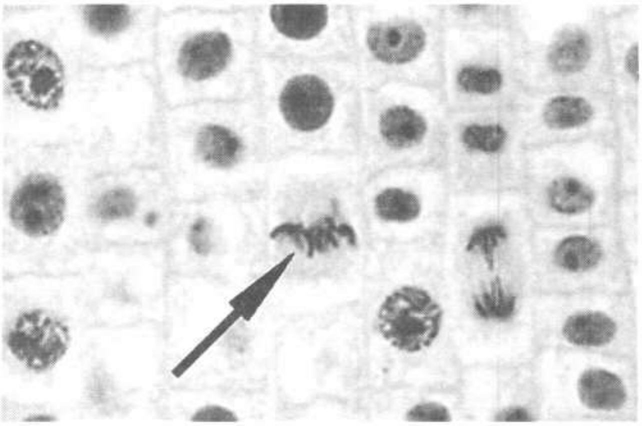
Processes of growth and development in any individual system, be it chemical or biological, are limited. Sooner or later any individual system comes to an end. Branched chain processes in an amino acid solution begin to fade when only a small portion of the amino acids, serving both as substrate and "fuel," is consumed. An individual living system also begins to "fade," even when all the energy/matter resources necessary for its existence are still available in its environment. That means that there must be some internal reasons for the fading of processes in such systems. What particular factors limit the process of life in an individual living system?

The "newborn" living system is already efficient, insofar as it possesses a certain stock of free energy. In addition, it has a certain initial potential that defines the amount of work it is able to perform during its life cycle. The provisional value of this potential was defined by Bauer as the ratio of initial stock of free energy of an ovum to the quantity of "active" (excited) mass it possesses. In actuality, the potential of an ovum can be estimated only *post factum,* based on the amount of work the living system has performed during its life cycle.

The initial stock of free energy of an ovum is minimal, whereas its potential is maximal. At the expense of potential, the system takes from its environment matter/energy having a lower potential than it has itself and uses it to replace old structures, and build new energy-charged structures, thus raising the potential of its acquired matter. During growth and development, the overall stock of free energy of the system increases; but its potential inevitably decreases. Finally, the potential is reduced to such a level that the system needs to expend more energy extracting matter and energy from its environment than it gains. On achievement of this state, defined by Bauer as "a limit of (active, excited) mass of the living system," further accumulation of active structures by the system becomes purposeless, as it is automatically accompanied by the reduction of its level of non-equilibrium. From such considerations, the final end of an individual life cycle follows with necessity. However, life as such is maintained and proceeds in a line of progeny.

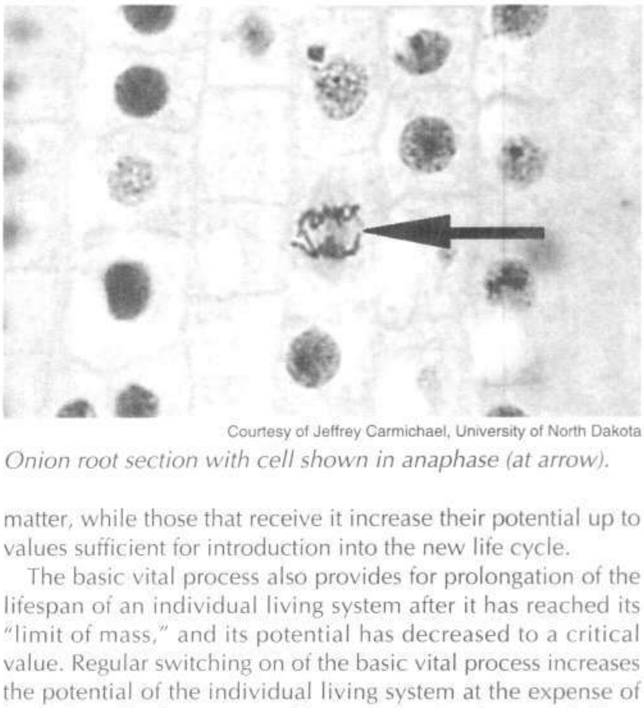
Bauer, apparently, was the first to comprehend the structure-energy foundation of the phenomenon of multiplication. He postulated, and then experimentally proved, that in addition to ordinary metabolism, another fundamentally different process takes place in living systems. This process ensures the unlimited existence of life; the essence of this basic, vital process is that within an individual living system, some of its parts transfer their free (structural) energy stock to a localized domain, where it becomes concentrated. The potential of matter in this domain increases accordingly. The phenomenon of such energy redistribution between different parts of a system, followed by an increase in the energy potentials of some parts over other ones, is known in physics and chemistry as "fluctuations." In the majority of lifeless physical-chemical objects (except systems in which branched chain processes occur), fluctuations occur casually and unpredictably. In a living system, the processes of energy redistribution occur according to law, and are strictly regulated.

Let us consider the life cycle of a unicellular organism as an example. The initial potential of a unicellular organism multiplying by simple division must be large enough to allow for the accumulation, during its life cycle, of a stock of energy, sufficient to provide the initial potential for a pair of daughter cells. Free energy accumulated during the life cycle of a parent cell must concentrate in a small domain, or to be more correct, in two small domains before its division. These domains will serve as the germs of two new daughter cells. Those cellular structures which donate their energy to others turn into lifeless



Courtesy of Jeffrey Carmichael, University of North Dakota

Section of an onion root showing a cell in metaphase (at arrow). Chromosomes are stained dark for visibility.



Courtesy of Jeffrey Carmichael, University of North Dakota

Onion root section with cell shown in anaphase (at arrow).

matter, while those that receive it increase their potential up to values sufficient for introduction into the new life cycle.

The basic vital process also provides for prolongation of the lifespan of an individual living system after it has reached its "limit of mass," and its potential has decreased to a critical value. Regular switching on of the basic vital process increases the potential of the individual living system at the expense of its getting rid of some part of its mass that has become ballast. It is interesting to speculate that the thoroughly studied process of "apoptosis"—the programmed cell death in a cellular complex—is a manifestation of such a process.

Homeostasis,[36] the physiological state in which the organism keeps its physiological parameters around certain stationary values, is probably an oscillation between intermittent metabolism, when the system performs internal and external work, and the basic vital process. Thus, during homeostasis, the vector of the life process oscillates between the accumulation of free energy and its expenditure, and between potential increase and decrease. However, sooner or later, the general stock of free (structural) energy of an individual system begins to decrease. When the vector of the life process turns this way, it means that a living system moves towards equilibrium with its environment. At this stage, Bauer's principles are increasingly shadowed with ordinary regularities of classical, in particular, statistical physics and chemistry. Certainly, manifestations of the purposefulness of the life process, and the inherent activity of a living system become less and less obvious, and are expressed as traces of previous development as a living system dies. It happens thus that the basic conclusions of modern biology are devised primarily from investigation of living systems, residing at best, at the stage of homeostasis and, at worst, at the final stages of the life cycle. Probably this is the reason for a misunderstanding of Bauer's principles of theoretical biology by the majority of biologists.

Gurwitsch's Theory of Cellular and Biological Fields

If we consider the development of a living system from the point of view of energy transformation, it represents the growth of stocks of free (structural) energy of the system. If we look at the "substantial" side of development, it looks like quantitative growth and qualitative transformation of "biomass" charged with structural energy, like the continuous emergence of new structures. During the development of any living system, specialized structures and organs arise in the space of the organism, giving it a specific form. The higher the structural organization of a living system, the higher the level of labor division among its parts, the more effectively it uses free energy, and the more sensitive it is to stimuli coming from its environment. What are the specific differences between the morphogenesis of living systems that takes place during its development, and the shaping that takes place during the growth of lifeless structures, for example, crystals?

Morphogenesis (development of shape) occurring in the embryo is primarily the result of individual cell movements and the change of their shape during differentiation, rather than the result of a multiplication of cells. The latter process is mostly responsible for the supply of new "building blocks" for the overall design. At the end of the 19th century, the prominent German embryologist Hans Driesch (1867-1941) proved on the basis of substantial experiments that all cellular reorganizations taking place during embryogenesis are determined primarily by particular cells' location in the space of a developing embryo taken as a whole, rather than by specific properties of these particular cells. He formulated one of the major laws of embryology: "The fate of a part of an embryo is the function of its location in the whole." It followed from this law that the properties of an integrated system are not just the combination or the sum of the properties of its parts. Driesch, however, limited further investigation of the nature of this law by ascertaining that an integral developing system possesses the special property which he named "Entelechia"—aspiration to development.[37] Such a formulation looks like a tautology, and appears fruitless for further scientific research. Driesch's theoretical concepts were mostly rejected by the scientific community.

A.G. Gurwitsch was one of a few who recognized Driesch's law as an extremely fruitful principle, helping to approach an understanding of morphogenesis and of other major vital manifestations from a uniform position.[38, 39] If the behavior of a given cell in an embryo depends upon its location in the whole, then one may consider the whole complex of cells forming an embryo as a certain geometrical space. Specific coordinate values relative to certain chosen axes may be ascribed to different points inside it. One and the same factor af-

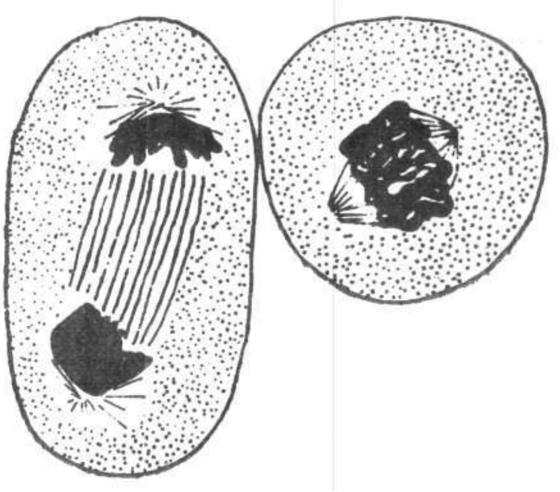


Figure 1

INFLUENCE OF ORIENTATION OF MITOTIC FIGURES ON THEIR MORPHOLOGY

During mitosis, the duplicated chromosomes must separate, and move away from each other into the area that will become the nucleus of the new daughter cells. Gurwitsch predicted that the vector of the biological field will be strongest along the axis of motion of the chromosomes, and that this field vector will extend beyond the border of the individual cell. In the case of two maternal microsporocytes (Larch), one of the daughter cells in telophase (left) is intersected by the vector of the long axis of the other cell in early anaphase, creating a displacement of the orientation of the mitotic figure.

Source: E. Puchalskaya 1947. "Morphological Alteration of Mitotic Figures Resulting in Their Interaction-An Attempt to Analyze Mitosis in Light of the Field Theory," in A.G. Gurwitsch, ed., *Collection of Works on Mitogenesis and the Theory of the Biological Field* (Moscow: USSR Academy of Medical Sciences Publishing House).

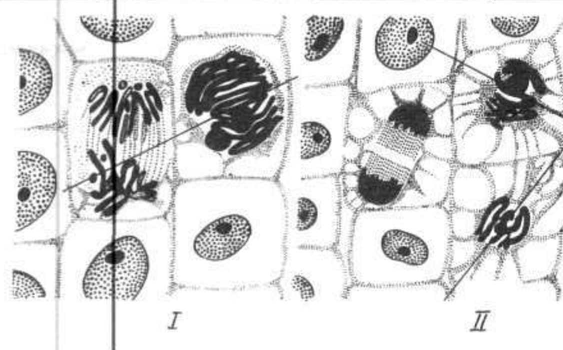


Figure 2

INFLUENCE OF ARRANGEMENT OF MITOTIC FIGURES ON THEIR MORPHOLOGY (ONION)

This tissue section of an onion shows the vectorial nature of the biological field in cell-to-cell interactions. The long axis of the prophase cell intersects one group of chromosomes in the adjacent anaphase cell, causing distortion (I). The long axis of the two adjacent prophase cells do not intersect the adjacent telophase cell, which remains symmetrical (II).

Source: E. Puchalskaya 1947. "Morphological Alteration of Figures Resulting in Their Interaction-An Attempt to Analyze Mitosis in Light of the Field Theory," in A.G. Gurwitsch, ed., *Collection of Works on Mitogenesis and the Theory of the Biological Field* (Moscow: USSR Academy of Medical Sciences Publishing House).

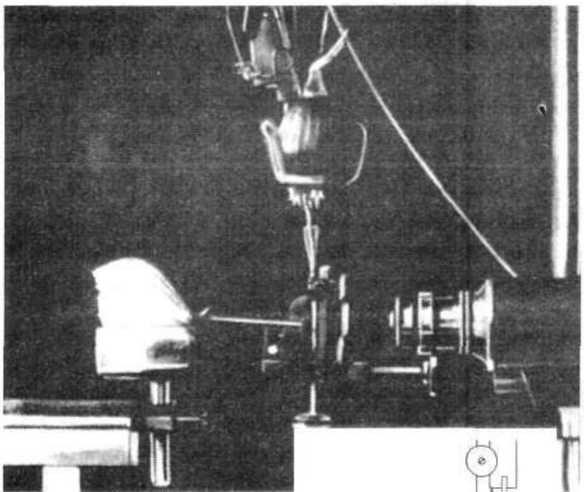
fects all the cells belonging to this space, but its parameters vary from one point to another. Gurwitsch put forward a hypothesis, according to which individual living cells produce elementary cellular fields, and a cellular field projects beyond the structural boundary of a cell. Individual cellular fields thus are able to interact, and as a result of their interaction, a synthetic field of a cellular complex is formed. This field is not just a superposition of individual cellular fields as far as it affects the properties of the latter; however, it reflects some specific properties of individual fields that give birth to it.

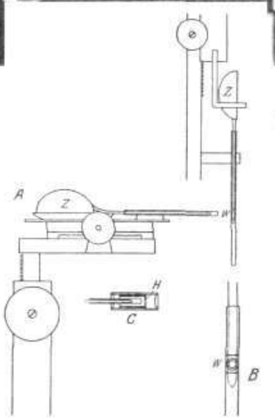
The major property of a cellular field is anisotropy. That means that its form is far from being simple, and that it is a vectorial field. Consequently, a synthetic field of a cellular complex is anisotropic, and the behavior of an individual cell in the collective will depend upon its coordinates in the space of the synthetic field. Another major property of a cellular field is its continuity in space and time. There are no living systems without a field; the cellular field divides as soon as a cell divides.

Based on data from cytology (microscopic examination of cells) and genetics, Gurwitsch assumed that chromatin, the DNA-protein complex specific for each particular organism, is the primary source of the cellular field. The major part of chromatin forms chromosomes, bearing the hereditary inclinations of an organism. Specificity of individual chromosome structures, determines specificity of the form of the field created by them. Since chromosomes are the most conservative structures of cells, anisotropy of the cellular fields of all the cells constituting the given organism is the same. Therefore the peculiarities of morphogenesis, of the hereditary peculiarities of any given living system, are reproduced in future generations. Any cellular field is both highly conservative and at the same time extremely dynamic: It creates in a cell the non-equilibrium dynamic molecular order and maintains it. The intensity of a cellular field depends on the intensity of cellular metabolism, a highly dynamic process, and in a feedback manner regulates the latter. Therefore, the intensity of a cellular field and, hence, of a synthetic field of a cellular complex fluctuates continuously. The overall form of a synthetic field is also far from being immutable: it varies with the multiplication of cells, their elimination, and their movements within the space of the synthetic field. Certainly, external factors can induce stable variations of developmental patterns (mutations), as soon as they are able to resonate with the synthetic field.

Impulses produced by a fluctuating field may excite elements sensitive to it and initiate branched chain processes in the sphere of its action. Excited molecules may form temporary associations, "constellations," in which they behave cooperatively, being in a resonance with each other. They spend the energy of excitation and free energy generated in branched chain processes for the performance of chemical, mechanical, or other forms of work; and they disassemble as soon as their energy is exhausted. The stable non-equilibrium (excited) state of molecular constellations provides an extremely high rate at which reactions in a living organism occur, in comparison

Gurwitsch's Famous 'Onion Experiment'





The cells at the root tip of a growing onion divide quickly. During growth, the circular cross-section, characteristic of the whole root, is maintained. Although individual cell divisions appear to occur in an unordered, even random distribution, the number of divisions in all directions from the axis must nevertheless be approximately equal. The root would otherwise not have a cylindrical form.

Gurwitsch supposed that at least some of the cells must be emitting light that regulated the rate of division of the other cells; he proved it by means of the experimental set-up shown here. The roots (W) of two onions (Z) were positioned perpendicularly, so that the tip of one root pointed to one side of the other root. He then examined under the microscope the second root, at the site facing the tip of the first root. He was able to establish a statistically significant increase in cell divisions there, compared to the opposite, "unirradiated" side.

This effect disappeared when he placed a thin piece of window glass between the two roots, and it reappeared when he replaced the window glass with quartz glass! That meant that ordinary glass is opaque for mitogenetic radiation, while quartz glass is translucent. Hence electromagnetic radiation must be operative, and ultraviolet light in particular, since it passes through quartz, but is stopped by window glass.

Source: A.G. Gurwitsch, *Das Problem der Zellteilung* (The Problem of Cell Division), 1926

with the same reactions' rate in vitro. A strict orderliness of reactions, affording an almost 100 percent yield of each reaction, is provided by a directing action of a field external to molecular "constellations," and induced by it. Each "constellation" is in continuous motion, contributing to the dynamic evolution of cellular and synthetic fields. Thus, all levels of organization of a living organism, starting with the molecular one, are sufficiently correlated.

The biological field concept allows one to discover the origin of the unique character of regulation in living systems. The behavior of a cell, being part of a certain cellular complex, certainly depends on the immediate state of the synthetic field. However, each cell is the source of its own field, and thus it is an autonomous system to a certain degree. Therefore, the general behavior of the cell is defined by the dynamic interaction between the synthetic field and its own cellular field. Such interaction should ensure harmony between the interests of the whole organism and its parts. If, for any reason, the behavior of a group of cells is determined by the "super authority" (the synthetic field) too rigidly, the cells' resources can be exhausted, resulting in elimination of these cells. Hence, cells should possess a certain degree of freedom not so much *from* the obligations of the organism, but *for* self-preservation of its parts. However, if cells isolate themselves too deeply from signals sent by the synthetic field, informing of the needs of the whole, if they permanently support only their selfish requirements, another dramatic consequence follows: Cells that take too much freedom, extreme individualists, turn malignant and inevitably perish—unfortunately, together with the whole organism.

The basic experimental fact favoring the existence of a high non-equilibrium of living systems and, consequently, of the existence of a field intrinsic to them, is the mitogenetic-laser electromagnetic radiation discovered by Gurwitsch. However, Gurwitsch never considered that a biological field could be reduced to some particular known physical field. He assumed that the biological field can be registered as an electromagnetic one and also as acoustic, thermal, chemical, mechanical, and so forth. The biological field may assume the aspect of that particular physical field, manifestations of which are studied by a researcher at a given moment.

Many consequences of the theory of a biological field have proved to be true experimentally. For example, Gurwitsch assumes that the cellular field extends beyond the structural borders of a given cell. This assumption serves as the precondition of the occurrence of a synthetic field of a cellular system. However, it also follows from this assumption that the synthetic field should expand beyond the structural borders of a cellular system, providing an opportunity for non-substantial interaction of kindred cellular systems. Several investigations have demonstrated that this assumption is supported by experimental data. If one excludes the opportunity of chemical interaction between two cellular populations, but leaves a physical channel of communication between them (for example, an optical one), excitation of one of the "partners" is accompanied by physiological changes in another.[40, 42] However, in most such experiments, it was demonstrated only that one population of cells is able to influence another by other than chemical means. Recently, we presented evidence that two samples of white blood cells,[43] or two samples of whole

NASA

"The emergence of mankind is a new leap in the integral process of our planet's development. With mankind, emerges a new form of energy, the energy of human culture, provided by the development of human reason. During the last millennia, precisely this form of energy steadily became the major geological force."

blood,[44] which were in optical, but not in chemical contact with each other, can really communicate. When phagocytosis (engulfing of external material) was induced in one of the samples, it affected properties of the other; and the latter, in its turn, influenced the character of the process taking place in the first one. Such interaction is strong evidence for the existence of individual fields intrinsic to both populations that are able to unite in a common (synthetic) field under certain circumstances.

Individual Development and External Environment

Bauer's principles and Gurwitsch's theory of the biological field complement and enrich each other. The former provides a basis for understanding the bioenergetics of developing living systems. The latter gives an idea of the organizing principle of the process of development. Stable non-equilibrium of a living cell gives birth to a cellular field. The latter, in its turn, coordinates structured processes occurring in its sphere of action. It is a source for the emergence of new forms, or put another way, of arousal of new structured processes, and of promoting the enhancement of steady non-equilibrium of a living system. It should be stressed that a synthetic field cannot arise without the interaction of at least two cellular fields. So, a single isolated cell possesses only a singular field, and only after its division does a synthetic field emerge.

However, as it has been mentioned, in order to divide, a cell has to receive an adequate impulse from the outside. This impulse interferes with its state of steady non-equilibrium, and initiates its division and the emergence of the synthetic field. Only after this event does the process of development of daughter cells start. It follows from the theory of the biological field that self-organizing processes in a developing system are driven for a certain period of time by the impulses coming from the synthetic field of this system. However, sooner or later, the system will be hampered in its development, because it will need to obtain a new portion of matter/energy from its environment. In order to perform external work, it needs to be stimulated again from the outside. Thus, any living system requires, for its harmonic development, fulfillment of at least two external conditions: first, availability of matter/energy resources in its environment sufficient to supply its constant progress in accumulation of structured free energy and, second, rhythmic inputs of adequate stimuli from the environment. The latter, on the one hand, breaks the stable non-equilibrium of the system, and on the other hand, stimulates external work performance by it. In an ideal case, the frequency of irritations (stimuli) should be coordinated with the internal rhythm of the system: If an impulse comes when the internal resources are still sufficient for the succession of a certain stage of development, it can break the normal course of its development, or even halt it. In order to initiate the following stage of development successfully, an impulse should come at that moment when the current stage has reached its climax.

Evolution of the Biosphere

In the previous discussion, we considered mostly a multicellular organism as an example of a living system. Bauer's principles and the theory of a biological field are most applicable to that stage of an organism's life cycle that is finished by reaching the reproductive stage of development. However, if one views the evolution of living nature as the development of a certain living system, it should obey the same regulations. All essential "parts" of the biosphere—biological species, families, orders—may be considered as lines of reproduction and multiplication of individuals, analogous to cellular multiplication during the development of a multicellular organism. Natural history is full of the emergence and disappearance of particular species in its course. However, there is no evidence for the complete disappearance of any highest order (kingdom) that ever emerged in the process of evolution. In fact, the overall process of evolution is characterized by the successive emergence of new kingdoms, new genera in these kingdoms, and new species in these genera.

Is there any objective evidence that the evolution of the biosphere as a whole goes in the direction of an increase of the stock of its (the biosphere's) free (structural) energy that provides its non-equilibrium stability? If this is the case, and if The Principle of External Work Increase As the Historical Trend works, one should find such species among forms that appear later in natural history, and that are "younger." These representatives should perform more external work during their individual life cycle than representatives of any species belonging to the kingdoms that emerged earlier. Both external and internal work performance need energy consumption, so different species may be compared from this point of view. In fact, according to physiological data, energy consumption in relation to "living" mass during the life-cycle period increases

Courtesy of Vladimir Voeikov

Alexander Leonidovich Chizhevsky (1897-1964), the founder of heliobiology, studied the effects of dynamic solar activity upon the biosphere, human health, behavior and activities. He also discovered the vital effects of negative ions in the air for all animals. He was a close friend and follower of Konstantin Tsiolkovsky, the first man who suggested the use of reactive engines for space flight.

Along with many outstanding Russian scientists, Chizhevsky was arrested by the NKVD and spent more than 10 years in the Soviet prison system known as the Gulag Archipelago. Even there, he found opportunities to perform scientific research, and studied the behavior of moving blood and the peculiarities of the erythrocyte sedimentation reaction, which has remained an enigma until now. In this field he made several important discoveries, which are very important for diagnostics, and which remain mostly unknown to Russian and foreign scientists and medical doctors.

several-thousand-fold in the sequence starting with primitive Coelenterates and ending with Primates.[45, 46] It is notable that for *Homo sapiens*, this parameter is at least one order of magnitude higher than for Primates. That means that *Homo* is drastically different from his allegedly closest "relatives," even in his physiology.

Bauer never applied his principles to the social sphere and limited himself mainly to considering the manifestations of living systems at the molecular, cellular, and cellular systems levels. Vladimir Vernadsky, who came to the same conclusions in respect to the biosphere as a whole, and who coined the term "biogeochemical energy" with respect to free energy of the biosphere, proceeded much further. He considered human history in the light of general principles governing the development of living systems and regarded it as a lawful progression of natural history.[47] The emergence of mankind is a new leap in the integral process of our planet's development. With mankind, emerges a new form of energy, the energy of human culture, provided by the development of human reason. During the last millennia, precisely this form of energy steadily became the major geological force. As the history of mankind progresses, its total energy consumption and transformation of external energy into free, "structural" energy, used for all kinds of work performance, undoubtedly increases. According to statistical data, both the total volume of energy powered by humanity, and of energy consumed per capita, grows from the end of the 18th century until recently in geometrical progression[48] (it is quite another question how these resources have been and are distributed among people and their communities).

Thus, Bauer's principles are quite justified by consideration of the evolution of the biosphere and even of mankind, as the process of development of an interlinked living system. Still, these principles are necessary but not sufficient for the construction of a more complete concept of the development of a living system. First, a "field factor" ensuring its integrity in time and space is necessary. Second, the development of any living system is a discontinuous process, consisting of separate stages. As was pointed out above, the previous stages do not automatically transit into the next, and an external impulse is needed to initiate a new stage of development.

The existence of such a global stimulus was discovered by the outstanding Russian scientist Alexander Chizhevsky in 1924. He found a strong dependence of behavior of organized human masses on factors stemming from space. In particular, he discovered a high correlation between the 11-year period of solar activity and important historical events.[49] Later he provided the evidence for correlation between cosmic rhythms and the most diverse phenomena in the biosphere: agricultural productivity, great epidemics, and the physical and mental state of great groups of people.[50] There are no indications that Chizhevsky was familiar with Bauer's and Gurwitsch's works. Nevertheless, in an effort to explain how very small changes of solar radiation flux or of geomagnetic field could have such profound effects, he came to ideas of non-equilibrium of living systems and the essential role of branched-chain processes in their functioning. He actually came to the understanding that all these phenomena represent particular manifestations of the reaction of the whole system, the biosphere, composed of, and uniting together, living systems at all levels of organization. Thus, an approach to the phenomenon of life as processes with a direction, taking place in bodies with special properties, and with different characteristics from lifeless systems, is not just a declaration.

The specificity of life has nothing to do with the powerlessness of scientific methods to comprehend its essential properties. An approach to living systems as non-equilibrium field-matter entities, possessing an inherited stock of free energy and using it to enhance their non-equilibrium state, does not reject—to the contrary, it includes—all knowledge of the manifestations of life already gained by science. Such an approach does not reject the idea that the particular processes in living nature proceed according to the known laws of classical physics, quantum mechanics, thermodynamics, and organic and inorganic chemistry. However, the specificity of life cannot be reduced to these laws alone, as it cannot be derived from them. The ideas of Bauer, Gurwitsch, Vernadsky, and Chizhevsky were decades ahead of their time, because they could not fit into the Newtonian-Cartesian world view that has dominated the natural sciences for centuries.

Today, a new world view is emerging. Post-quantum physics is ready to accept the biocentric, if not the consciousness-centric, perception of nature. More and more representatives of the scientific community acknowledge that research based only on imitations, or on the study of lifeless nature or dying fragments of living systems, will not help to achieve a decisive breakthrough in understanding the laws of life. The time is coming when biology will give a tremendous new impetus to the metamorphosis and accelerated development of physics and chemistry.

The complementation, coherence, and coevolution of natural sciences now emerging raises hope that a human being, as a learning subject, creating and building any form of science, will come to understand that the world he belongs to is neither a set of separate parts and phenomena, nor a tragically breaking off, degenerating whole. Comprehension of the primacy of the phenomenon of life will allow him to distinguish a steady vector of development heading towards ever greater coherence of the Universe, amid the tremendous complexity of natural bodies and processes. If such a realization comes about, it will give a human being a new chance to feel that he personally is an inseparable part—and at the same time, the most unique part—of this continually emerging Universe, and that without his cooperation its development will be retarded.

Dr. Vladimir Voeikov is Associate Professor and Vice Chairman of the Department of Bioorganic Chemistry, Faculty of Biology, at M.V. Lomonosov Moscow State University in Moscow, Russia.

Notes

1. M. Hartmann, 1935. *General Biology. Introduction to the Science of Life.* Moscow: State Publishing House of Biological and Medical Literature, Translated from German, 2nd Edition, p. 21.
2. *Biological Encyclopedic Dictionary.* 1986. "Biology," Moscow: Soviet Encyclopedia, p. 66.
3. R. Dawkins, 1993. *Egoistic Gene.* Moscow: Mir Publishers, p. 9.
4. Yu. A. Ovchinnikov, 1987. *Bioorganic Chemistry.* Moscow: Prosveshchenie.
5. J. Bernal, 1969. *The Origin of Life.* Moscow: Mir Publishers, pp. 209-210.
6. J.G. Simpson, 1967. *The Meaning of Evolution.* New Haven: Yale University Press, p. 279.
7. M. Planck, 1925. *From Relative to Absolute.* Vologda, pp. 15-16.
8. V.I. Vernadsky, 1994. "The Beginning and Eternity of Life." In: V.I. Vernadsky, *Living Substance and Biosphere.* Moscow: Nauka, p. 282.
9. B.P. Tokin, 1963. *Theoretical Biology and the Creative Work of E.S. Bauer.* Leningrad: Leningrad State University Printing House.
10. L.V. Beloussov, A.A. Gurwitsch, S. Ya. Zalkind, and N.P. Kanegisser, 1970. *Alexander Gavrilovich Gurwitsch.* Moscow: Nauka.
11. L.V. Beloussov, V.L. Voeikov, and F.A. Popp, 1997. "Gurwitsch's Mitogenetic Rays." *Priroda* (Nature), Moscow, No. 3, pp. 64-80.
12. V.N. Yagodinsky, 1987. *Alexander Leonidovich Chizhevsky.* Moscow: Nauka.
13. D.A. Sabinin, 1963. *Physiology of Plant Development.* Moscow: USSR Academy of Sciences Publishing House, pp. 6-9.
14. E.S. Bauer, 1935. *Theoretical Biology.* Moscow-Leningrad: VIEM Publishing House.
15. A.G. Gurwitsch, 1923. "Die Natur des spezifischen Erregers der Zellteilung." *Arch. Entwicklungsmech.*, Vol. 100, No. 1/2, pp. 11-40.
16. S. Ya. Zalkind, 1937. "The modern state of the problem of mitogenetic emission and contemporary positive data." *Uspekhi Sovr. Biologii*, Vol. 7, pp. 216-33.
17. A.G. Gurwitsch and L.D. Gurwitsch, 1945. *Mitogenetic Radiation: Physical-Chemical Foundation and Application in Biology and Medicine.* Moscow: Medgiz.
18. H. Berth, 1936. *Biochem. Zeitschrift,* Vol. 285, pp. 311-39.
19. R. Audubert. *Trans. Faraday Soc.*, Vol. 213, pp. 98-206.
20. F.A. Popp, Q. Gu, and K.H. Li, 1994. "Biophoton emission: experimental background and theoretical approaches." *Modern Physics Letters B,* Vol. 8, pp. 1269-96.
21. A.A. Gurwitsch, 1968. *The Problem of Mitogenetic Radiation As an Aspect of Molecular Biology.* Leningrad: Meditsina.
22. L.V. Beloussov, 1996. In: *Non-Equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology.* Moscow: BioInform Services, pp. 167-190.
23. I. Prigogine, 1967. *Introduction to the thermodynamics of irreversible processes.* New York, 3rd ed.
24. H. Haken, 1978. *Synergetics, An Introduction.* Berlin, Heidelberg, New York: Springer-Verlag.
25. N.N. Semyonov, 1935. *Chemical kinetics and chain reactions.* Oxford: Oxford University Press.
26. C.N. Hinshelwood, 1940. *The Kinetics of Chemical Change.* Oxford: Clarendon Press.
27. C.N. Hinshelwood, 1966. "The probable role of chain reactions in the chemistry of the cell." In: *Chemical Kinetics.* Moscow: Nauka, p. 518.
28. N.N. Semyonov, 1981. *Science and Society.* Moscow: Nauka, p. 365.
29. *Free Radical Processes in Biological Systems.* 1966. Moscow: Nauka.
30. N.M. Emanuel, 1966. "Kinetics of Some Biological Processes." In: *Chemical Kinetics and Chain Reactions.* Moscow: Nauka, pp. 551-8.
31. A.G. Gurwitsch and L.D. Gurwitsch, 1942. "Peculiarities of chain reactions and common energy levels in living systems." *Acta Phys. Chem.*, Vol. 16, p. 288.
32. V.L. Voeikov and I.V. Baskakov, 1995. "Study of chemiluminescence kinetics in aqueous amino acid solutions in the presence of hydrogen peroxide and ethidium bromide." *Biofizika,* Vol. 40, No. 6, pp. 1150-57.
33. I.V. Baskakov and V.L. Voeikov, 1995. "Temperature dependence of chemiluminescence in aqueous solutions of aspartate in the presence of hydrogen peroxide and ethidium bromide." *Biofizika,* Vol. 40, No. 6, pp. 1141-9.
34. V.L. Voeikov, et al. 1996. "Initiation of degenerate-branched chain reaction of glycine deamination with ultraweak UV-irradiation or hydrogen peroxide." *Bioorganicheskaya Khimiya,* Vol. 22, No. 1, pp. 39-47.
35. I.V. Baskakov and V.L. Voeikov, 1996. "Formation of a polymer with the activity of glycine deaminase upon UV-irradiation of solutions of amino acids." *Bioorganicheskaya Khimiya,* Vol. 22, No. 2, pp. 94-100.
36. W.B. Cannon, 1932. *The Wisdom of the Body.* London: Kegan Paul and Co.
37. H. Driesch, 1915. *Vitalism: Its History and System.* Translated into Russian by A.G. Gurwitsch. Moscow: Nauka.
38. A.G. Gurwitsch, 1914. "Der Vererbungsmechanismus der Form. *Archiv. Entwich. Mech.*, Vol. 39.
39. A.G. Gurwitsch, 1944. *Theory of the Biological Field.* Moscow: Sov. Nauka.
40. X. Shen, W. Mei, and X. Xu, 1994. "Activation of neutrophils by chemically separated but optically coupled neutrophil population undergoing respiratory burst." *Experientia,* Vol. 50, pp. 963-8.
41. V.P. Galantsev, S.G. Kovalenko, A.A. Moltchanov, and V.I. Prutskov, 1993. "Lipid peroxidation, low-level chemiluminescence and regulation of secretion in the mammary gland." *Experientia,* Vol. 49, pp. 870-5.
42. V.P. Kaznacheev and L.P. Mikhailova, 1981. *The Role of Ultra-Weak Emissions in Intercellular Communication.* Novosibirsk: Nauka.
43. C.N. Novikov, V.L. Voeikov, and F.A. Popp, 1995. "Analysis of light emission by neutrophils in the process of respiratory burst suggests that physical fields are involved in intercellular communications." In: *Biophotonics: Non-equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology.* Proc. Int. Conference Dedicated to the 120th birthday of A.G. Gurwitsch. Eds. L.V. Beloussov and F.A. Popp. Moscow: Bioinform Services, pp. 291-302.
44. V.L. Voeikov and C.N. Novikov, "Interaction of two optically coupled whole blood samples in the course of respiratory burst in one of them." *SPIE Proc. EuriOpto Series.* Vol. 2925. *Photon Propagation in Tissues II.* 1996. Eds. D.A. Benaron, B. Chance, and G.J. Muller. Vienna, pp. 269-77.
45. V.R. Dolnik, 1968. "Energy Turnover and Animal Evolution." *Usp. Sovr. Biol.,* Vol. 66, No. 5, pp. 276-93.
46. A.I. Zotin, 1984. "Bioenergetic Direction of the Evolutionary Process of Organisms." In: *Thermodynamics and Regulation of Biological Processes.* Moscow: Nauka, pp. 269-74.
47. V.I. Vernadsky, 1991. *Scientific Thought as a Planetary Phenomenon.* Moscow: Nauka.
48. I.S. Shklovsky, 1980. *Universe, Life, Consciousness.* Moscow: Nauka, pp. 318-20.
49. A.E. Chizhevsky, 1924. *Physical Factors of the Historical Process.* Kaluga.
50. A.E. Chizhevsky, 1973. *Earthly Echo of Solar Storms.* Moscow: Mysl.

The Discovery of Nonlinear Waves In the Ocean's Near-Surface Layer

by Robert E. Stevenson, Ph.D.

Solitons, suloys, and spiral eddies are the turbulent phenomena that make up the near-surface layer of the ocean—defying linear computer models that describe ocean and climate dynamics. America's pioneer space oceanographer reports on how they were discovered from space.

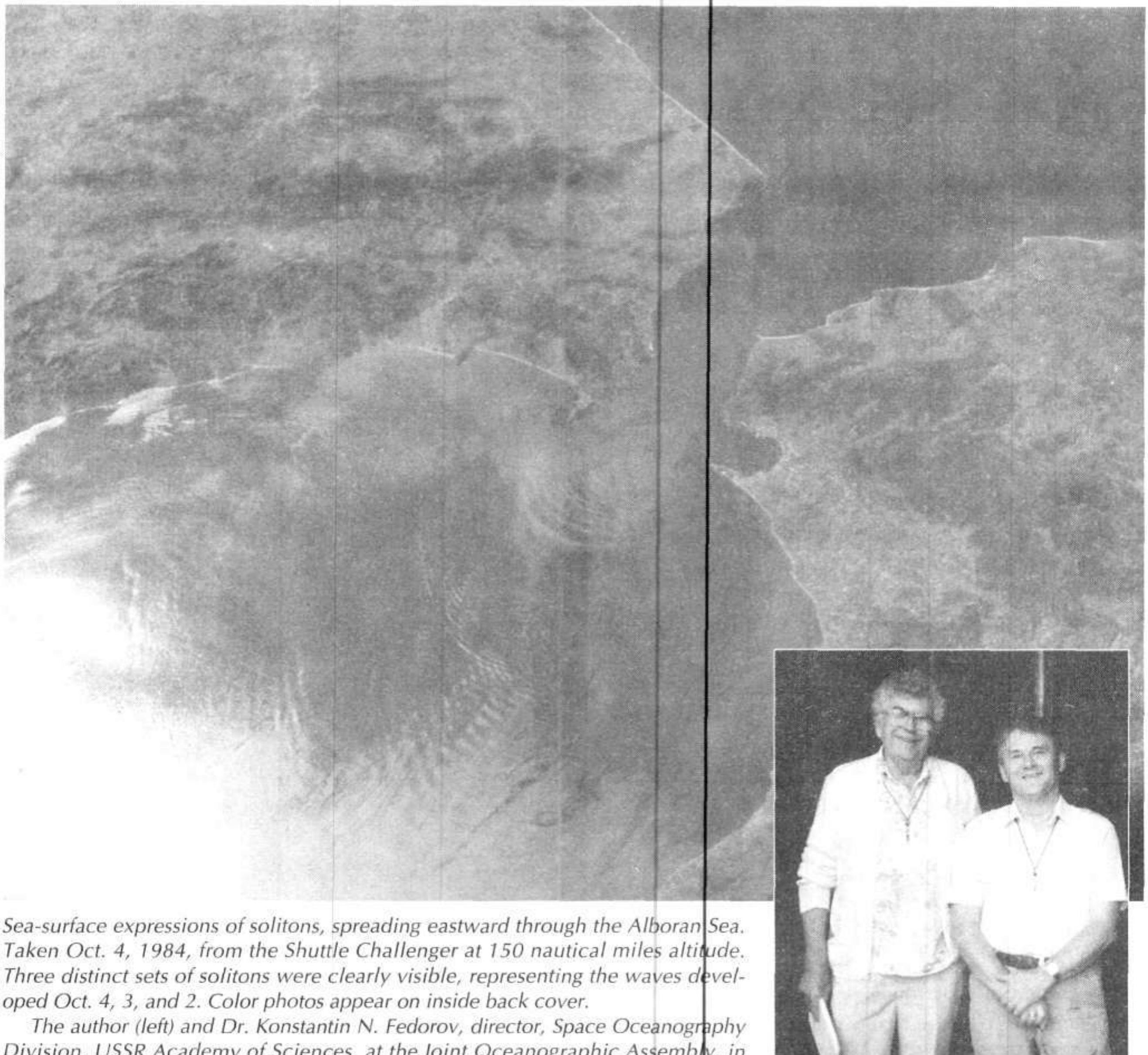
As oceanographers gathered in Acapulco, Mexico, in September 1988, for the sixth Joint Oceanographic Assembly, they did so with eager anticipation of the potentially exciting new research to be reported. Most of the scientists remembered the tremendous gains in knowledge since the first Assembly in 1959: The discovery of plate tectonics, the determination that eddies were the major part of the ocean's kinetic energy, and the huge advances in our understanding of the fluxes of gases, fluids, and energy throughout the ocean-atmosphere system.

By the late 1980s, the impact of space-borne technology and computer Global Circulation Models seemed to promise leaps of comprehension that could unravel the details of interactions between regional weather and worldwide climate change. Those who had developed the Global Circulation Models, had, it seemed, become the "crown princes" of oceanography. All were eager to experience their progress.

At all the Joint Oceanographic Assemblies, the organizing committees invited outstanding scientists in the pertinent fields of oceanography to present an evaluation, at the end of the meeting, of the growth and status of the field of their respective specialty. At Acapulco, the program in physical oceanography was produced by the International Association for the Physical Sciences of the Oceans, of which I was the Secretary-General. We had chosen Dr. Konstantin N. Fedorov, Director of Space Oceanography for the Soviet Academy of Sciences, as the evaluator of our program.

Fedorov was the leading physical oceanographer in the Soviet Union at that time, not only competent in space oceanography, but well versed and experienced in all aspects of the physical ocean. He and his wife, Dr. Anna Ginsberg, outstanding in her own right, had just published a major book, *The Near-Surface Layer of the Ocean*. The book was in Russian, yet to be translated, so had there been no participation by Fedorov in the Assembly, the fundamental oceanographic concepts they presented would not have been realized. The boundaries and dynamics of the near-surface layer of the ocean, as defined by Fedorov, staggered the physical oceanographers—and sent the computer modellers home, questioning the veracity of years of work.

The two Soviet oceanographers had shown that the near-surface layer was not controlled by the underlying ocean! It was not, therefore, subjected to geostrophic movements; that is, to the dynamic flow of the major ocean currents. Recognizing that it is through the near-surface layer that all heat, salts, gases, moisture, and momentum are exchanged with the atmo-



Sea-surface expressions of solitons, spreading eastward through the Alboran Sea. Taken Oct. 4, 1984, from the Shuttle Challenger at 150 nautical miles altitude. Three distinct sets of solitons were clearly visible, representing the waves developed Oct. 4, 3, and 2. Color photos appear on inside back cover.

The author (left) and Dr. Konstantin N. Fedorov, director, Space Oceanography Division, USSR Academy of Sciences, at the Joint Oceanographic Assembly, in Acapulco, Sept. 1988.

Courtesy of Robert Stevenson

sphere, it became apparent that no General Circulation Model could address any climate or weather changes without including and defining these near-surface layer processes.

As they wrote:

> . . . [I]t is a thin layer, ranging to depths of from several meters to one or several tens of meters, adjoining the free surface of the ocean directly from below and including this surface, the thermal boundary layer, the diurnal [daily] thermocline, and all the stratifications that arise because of higher frequency processes and non-periodic atmospherics effects. The near-surface layer absorbs solar radiation directly and reacts to heating, cooling, evaporation, and freshening caused by local conditions of the atmosphere as well as to near-surface water exchange from neighboring areas.

Now, most of these dynamic activities were known, to all oceanographers and meteorolgists versed in the physics and chemistry of the ocean. The kicker, however, is that through this layer flow, in and out, all of the factors that are addressed in ocean, weather, and climate models. And, this layer "floats" around the top of the ocean, independent of the flow of the known, major ocean currents—those things that we can model! Holy Cow, was our response.

Thus, any model that addresses the long- and short-range ocean, weather, and climate trends, or variability, must include any modifications in the near-surface layer, especially, the extent, periodicity, cyclicity of the changes; or, at least, these variables must be anticipated. There is little question but that solitons, internal waves, wind waves, suloys, and spiral eddies (Stevenson 1998) are direct, physical, enormously interactive moderators of the near-surface ocean.

Sea-surface expressions of solitons in the Andaman Sea, observed and photographed by Vance Brand, July 23, 1975, from the Apollo spacecraft, after undocking from the USSR's Soyuz. The southern Andaman Islands are in the foreground; the Burma shore is at the top. Inset: Astronaut Vance Brand coming from Soyuz, into the Apollo spacecraft through the docking tunnel.

The Waves—Nonlinear and Otherwise

From space, the oceanographer has the advantage of evaluating and determining the area of distribution of the upper-ocean processes at scales and repetition rates not possible from any other platform. The benefits from this capability are enormous, for there is no other way to examine, with any satisfaction, turbulent motion at scales of from one to a few hundred kilometers.[1] Spiral eddies, and the suloys and solitons discussed here, were not known—or even suspected—until observations and photographs in space were possible.[2] This capability must be weighed with the quantitative precision of the data required for the ocean processes under study.

The ocean's surface also, of course, may be observed from ships and aircraft. As from space, data can be gathered in response to the sea's own visible, infrared, or radio-wave radiation. In each radio wavelength, intriguing and useful measurements have been made from all three platforms, and from land stations as well. In every instance, when remote sensing has been coupled with *in situ*, simultaneous "conventional" oceanographic measurements, the two sets of data have been remarkably comparable.

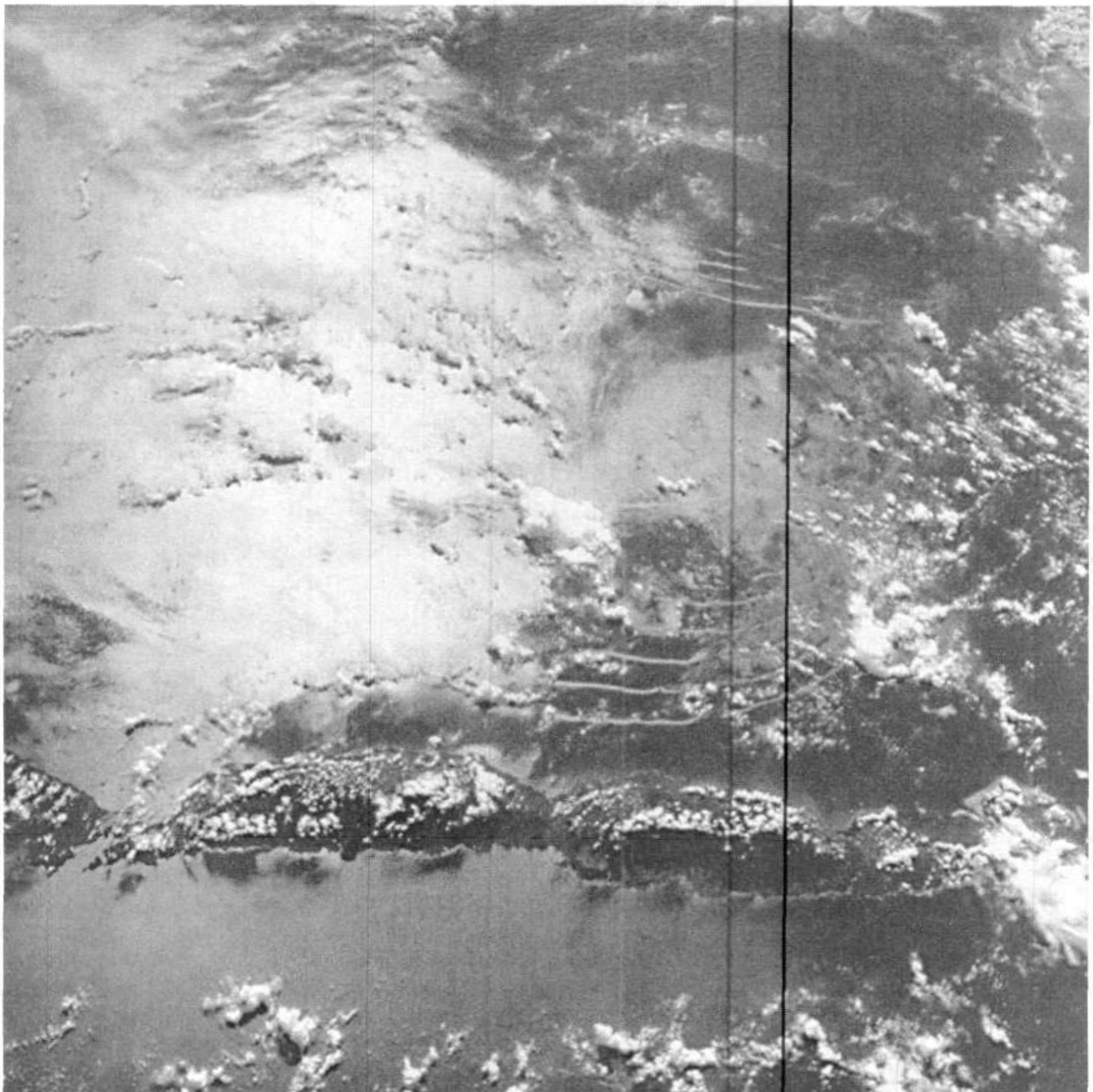
Solitons: Discovered in 1975

The first information that solitons exist in the ocean came from a 35-mm photograph taken alertly by Vance Brand from the Apollo capsule, in July 1975, after the American ASTP (Apollo-Soyuz Test Project) crew had undocked from Soyuz:

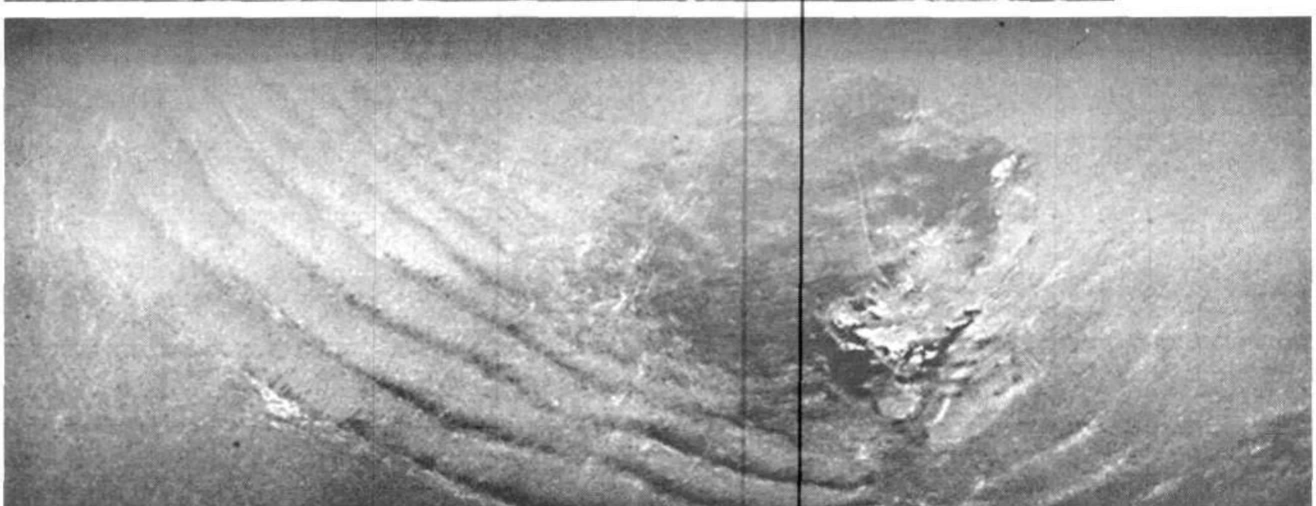
> As we orbited west of the Andaman Sea, the Sun was just right to give a good glint from the ocean surface. I saw what looked like huge internal waves and clicked off three shots with the 35-mm camera. We were all out of 70-mm film by then.

An important part of Earth observations during ASTP was of internal waves. In every one of the several pre-flight briefings, the significance of learning their distribution throughout the ocean had been stressed. As a result, in the last day of the mission, and even though all of the 70-mm Hasselblad film had long since been exposed, Vance was still looking for internal waves, and prepared with the 35-mm Nikon. From this observation and photography by Vance, oceanographers were to learn that internal soliton waves existed in the ocean.

When the ASTP photograph (above) came to the attention of Dr. A.R. Osborne at the Exxon Research Laboratory, Houston, it gave him the clue he needed to explain measurements made from Exxon exploratory drilling platforms in the Andaman Sea. In his classic paper, he explained the waves as "travelling" internal solitons with propagation rates around 2.2 m/sec and amplitudes of 60 m. The surface expressions caught in the



A view to the southeast, across the Sulu Sea, from the Shuttle Endeavor, Dec. 10, 1993, with Palawan Island in the foreground. Two sets of solitons were seen, extending northeast-southwest, having been generated in the wide, island-choked pass between Zamboanga and North Borneo.



Solitons refracting around unnamed seamount in the northern Andaman Sea, imaged from the synthetic aperture radar aboard the Columbia, at 140 nautical miles, on Nov. 13, 1981. The white dots at the base of the image represent one second of time, about 5 nautical miles Earth-surface distance.

photograph matched Osborne's observations of long (150 km) bands of short, breaking waves (600 to 1,200 m wide) at the front edge of the soliton crests, 15 km apart, travelling across the sea surface at the soliton's speed.

That Osborne would make the satisfactory determination that the Andaman Sea internal waves were solitons provides us with an interesting example of the ways of science.

A few years later in the Sulu and Celebes seas, a team led by Dr. John Apel of Johns Hopkins University, studied solitons using visible-range satellite imagery and simultaneously they collected data from research vessels. It was clear that solitons were not indigenous to the Andaman Sea, but appeared in any enclosed sea where narrow entrances permitted their generation (see photo, p. 37, top).

Back to the Andaman Sea

From the synthetic aperture radar (Shuttle Imaging Radar—SIR-A) flown in 1981 on STS-2, images of solitons were again acquired in the Andaman Sea, in this case, with Col. Joe Engle and Capt. Dick Truly flying the Columbia. The huge, subsurface waves were refracting around a submerged mountain peak whose top rose only to within 600 meters of the sea surface (see photo, p. 37). It was clear that the solitons were travelling in the same northerly direction as those observed by Vance Brand in 1975, but at this time, November 1981, they were wrapping around the seamount at a depth of nearly 1,500 meters!

The SIR-A image of the Andaman-Sea solitons was good evidence that these huge, nonlinear waves are routinely travelling through those waters off "Burma 'cross the sea." They surely were not generated only at times when a U.S. manned spacecraft orbits overhead. We reasoned that if soliton generation is a continuous process there, then it seemed likely that they could be constant features in other confined seas with restricted entrances.

And then, to Gibraltar: So it was that a major experiment was planned for Shuttle mission 41-G, September-October 1984, during which Dr. Paul Scully-Power would fly as the

Dr. Paul Scully-Power (right) with Marc Garneau, Canadian payload specialist, training for the 41G mission of the Shuttle Challenger, Sept.-Oct. 1984.

A Gallery of Upper Ocean Waves

O*bservable Waves.* The entire spectrum of waves occurring in the upper ocean is observable from space. From capillaries, to internal waves with lengths of kilometers, these waves modify the surface texture in recognizable patterns. The open-ocean tide wave is not observable, although the ability to follow it around the globe, and through the ocean basins, seems a possibility, should anyone care to do it, from data gathered routinely from an orbiting radar altimeter. There are, though, manifestations of tidal action that permit continuous analyses from space observations; especially where the daily tidal surge through straits, into embayments and gulfs, and across enclosed seas produce either internal waves or turbulent current shears.

The reaction of waves to coasts, both insular and continental, result in readily visible patterns. Refracted and reflected waves, and island bow and wake waves, not only are observable, but their reaction with currents at a range of velocities is measurable. Even the intriguing, but short-lived waves from ships produce surface features that respond to remote sensing in all three of the primary bands of the electromagnetic spectrum.

The only wave of any significance that escapes observation from any platform, including ships at sea, is the tsunami, popularly known as a tidal wave. Tsunamis originate from (1) submarine earthquakes where there is a major vertical displacement of the sea floor, (2) substantial submarine volcanic eruptions, (3) eruptions of volcanic islands in which a large part of the explosion is below the sea surface, or (4) sudden landslides of the upper-ocean sea floor, especially in

Destructive surf, late in the sequence, during the tsunami, April 1, 1946, breaking through 100-foot palms on Coconut Island, Hilo, Hawaii.

F.P. Shepard, *The Tsunami of April 1, 1946,* (University of California Press, 1950)

embayments or small confined basins. Their lengths are as long as 1,500 miles, their heights are from the sea floor to the surface, and their speeds are hundreds of miles per hour. The crest widths are so wide (upwards of 50 miles) that they are lost from view in the open ocean among all of the wind-waves and ocean swell.

The impact of these huge waves can be dramatic on coasts exposed to their full force. The stories of the destruction by the tsunami created when Krakatoa erupted in 1887 among the islands of Indonesia have become legendary. There were also excellent data and information obtained during and after the 1946 tsunami that struck the Hawaiian Islands. At that time, the late Dr. Francis P. Shepard joined Army Engineers, Navy personnel, and geologists from the University of Hawaii (Doak Cox and Gordon MacDonald) to help in the most extensive examination ever conducted on the destructive effects of a tsunami on a coast or island (see photo above and p. 38).

Obviously, the occurrence of tsunamis in the Pacific Ocean is of keen interest to the population both on the islands and the continental shores. Research, warning systems, and evacuation plans were initiated after the 1946 disaster.

The Wind-Derived Wavy Surface

Winds blowing across the sea form waves on the surface. Both gravity and surface tension act simultaneously, so that the length of the wave being formed by wind action is determined by which dominates at any given time. Capillary waves, or ripples, with lengths of 0.4 cm, or less, are basically controlled by surface tension, gravity being totally insignificant. But in the case of waves with lengths greater than 10 cm, gravity is the dominant factor and, for that reason, they are called "gravity waves."

At wind speeds of less than 1 meter/sec, capillary waves form on an otherwise calm surface. They arise quickly in response to wind gusts, forming "cats paws" on the surface. They disappear just as quickly as the little gusts pass by, molecular viscosity taking over to smooth the water's surface. Gusty conditions usually lead to a surface that has both gravity waves and ripples scattered widely across their surfaces.

Winds blowing at greater than 1 m/sec begin to form gravity waves. The characteristics of gravity waves are determined by their length, amplitude, and the depth of water through which they are moving. In depths greater than half the wavelength, individual water particles rotate in basically circular orbits, hardly mixing or moving forward in the direction the wave is progressing, with the orbits decreasing exponentially with depth. The maximum height attained by wind waves depends on the wind speed, the amount of time it continues to blow, and the distance of ocean over which it blows (called the fetch). Basically, at any given wind speed, it is the length of time and the fetch that determine the height of the resulting waves.

As wind waves grow under the attack of the wind, their distribution is random; the winds are never constant in either direction or speed. Therefore, any description of them is statistical, giving a range of wave spectra, heights, frequencies, and directions of propagation. The speed of propagation of wind waves is close to the average of the wind that prevails at the time. In a typical range of winds, say 10 to 30 m/sec, wavelengths range from 60 to 600 m, wave periods from 5 to 20 sec, and heights from 2 to 20 m.

Waves with greater heights and lengths than those have been experienced (even recorded in a few cases) during hurricanes in which winds blow around 50 m/sec. Although it is not an easy measurement, reliable data indicate waves can form up to a height of 40 m with lengths approaching 1,000+ m. Such waves are restricted to those violent storms, though, and to the 40° latitudes (the Roaring Forties) of the southern ocean. For the most, part, waves rarely exceed 12 m in the Atlantic Ocean and 15 m in the North Pacific.

Whitecaps. Observations of whitecaps atop wind waves are readily made by astronauts, but only resolved by excellent photography. No sensing systems other than the "eyeball" and cameras, preferably with focal lengths longer than 250 mm, have the necessary resolution.

The distribution of whitecapped seas is but poorly known, from space, or any other kind of observations. This lack is probably because of the conditions under which whitecaps are formed. The whitecaps have to be fairly large to be seen from low-Earth orbit. In general, that means a wind speed greater than 15 m/sec (Beaufort Force 7), to produce "foam from the breaking crests blown in streaks along the direction of the wind." Yet, under such wind conditions, all the spray, foam, and aerosols thrown into the marine air reduces the visibility, no matter what the observing direction many be. Furthermore, winds of such speeds are usually born of a good cyclonic storm with an extensive cloud cover.

The best chance of observing a foamy, whitecapped sea is behind a cold front, when the wind speeds remain high and the overlying atmosphere is clear and dry (See photo, p. 43, top left.) Or, from katabatic, down-slope winds blowing from the Alps through the elongated seas of the northern Mediterranean. Whenever astronauts observe whitecaps, they are at first surprised that the ocean surface appears "indistinct," as though the spacecraft window has become hazy. Almost immediately, however, they realize that any nearby coastal

Continued on page 42

first oceanographer in space (see photo, p. 38, bottom). The Strait of Gibraltar was the site.

The oceanography of internal waves, formed on a density-boundary at 125 meters, moving through the Strait into the Alboran Sea had been known since the cruises by Albert Defant aboard the *Meteor* in the 1930s. There had been no consideration that the Gibraltar internal waves were solitons. After all, they were unknown in the sea—then.

But even if not, the orbits for the mission and the Sun angles during the times when the Shuttle would cross over the Strait gave the opportunity to observe the internal waves in detail never before possible. Oceanographers from the Navy Research and Development Activity (NORDA), Bay St. Louis, Mississippi, had a continuing research effort on the effects of the Atlantic inflow through the Strait on the Alboran Sea. Those scientists would provide excellent support for the observations from space.

Viewing conditions from the flight deck of the Shuttle Challenger were perfect throughout the entire 41-G mission. So, too, was the weather over the waters of the strait for the flights of the helicopter from Gibraltar and the U.S. Navy long-ranged patrol aircraft flying out of Rota, Spain. As recorded in an in-flight, taped report by Paul Scully-Power during the Shuttle mission, 41-G:

> On three different days, the Sun's glitter was just right for us to observe, and photograph, solitons punching through the Strait of Gibraltar—they continued to spread into the Alboran Sea. From one orbit over the eastern end of the Alboran, it appeared as if they go all the way to the western Mediterranean.

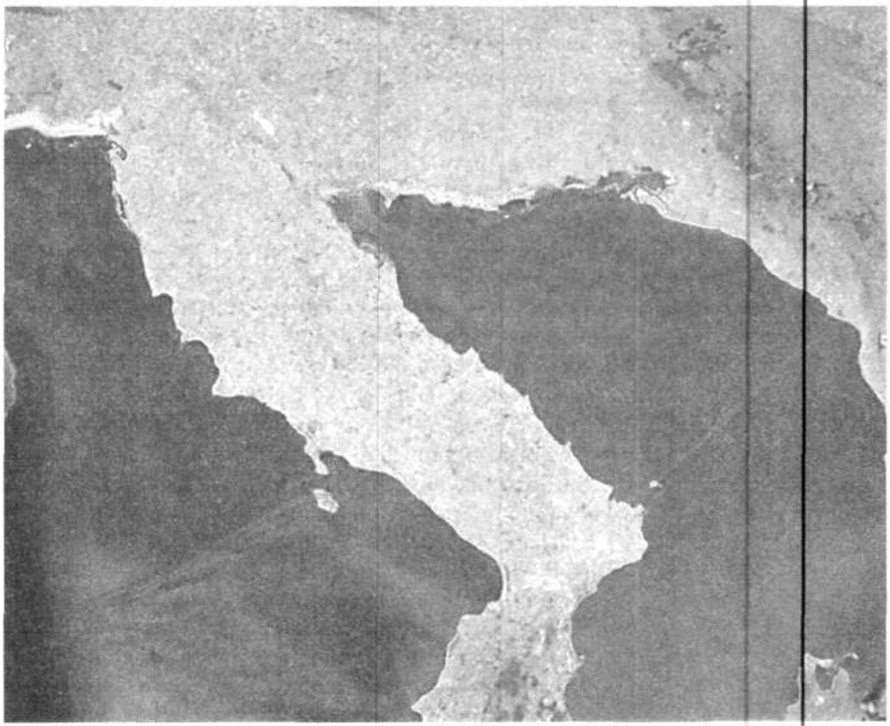
The photography (see p. 35) showed his observations to be correct: The internal solitons extended through the Alboran Sea, representing three to four days of tidal forcing through the Strait of Gibraltar. Every day, the internal waves spread through the strait into the Alboran Sea. Even though the crew aboard the Challenger was not privy to the water temperatures and the wind data being collected by the scientists from NORDA, it was easily apparent to them that the waves formed as solitons. Initiated at the sill in the western part of the Strait of Gibraltar—the shallowest part of the strait at 320 meters—pushed once a day by the highest of the diurnal tides, the waves were easily observed passing through the east end of the Strait and into the Alboran Sea. Showing little dispersive effects, the soliton "packets" crossed the sea between Spain and Morocco. So much of their surface expressions remained, that from space, waves formed during the preceding three days were observable!

The observations of the solitons from 41-G were so impressive that the Office of Naval Research mounted an oceanographic experiment to examine the waters in the strait and the adjacent Alboran Sea, from the fall of 1985 through October 1986. Thirty-seven scientists from five countries brought equipment that measured every conceivable meteorologic and oceanographic parameter: currents, winds, temperature, salinity, backscatter from shore-based and airborne radar (from a weary B-17 Flying Fortress), sea-floor pressure, and sea level. Even the water's trace elements and nutrients were all measured in the greatest "oceanographic attack" on the Strait of Gibraltar in history.

Eddies in the eastern Alboran Sea, seen from the flight deck of the Shuttle Endeavor, May 23, 1996, at 155 nautical miles.

The results were more than predicted, mainly because of the great quantity and variety of the data that were collected. Thirteen papers were published during and within a few months of the experiment. Beyond the mere presence of tidally generated solitons, knowledge of the flow into and out of the strait is now exceptionally complete. And, as is always the case, the scientific analyses produced as many questions as they answered. There is surely more to be learned from future observations of the Strait of Gibraltar.

There was one curious aspect from the observations over the Mediterranean Sea during 41-G, on which Paul Scully-Power, other Navy oceanographers, and I were to contemplate over more than one beer. From the geographic eastern end of the Alboran Sea throughout the remainder of the Mediterranean, interwoven fields of spiral eddies were continuously viewed. Yet, there were



Tidal bore, with suloys atop, spreading into Spencer Gulf, taken by the Shuttle Endeavor, at 170 nautical miles altitude. Note the city of Adelaide at the head of the estuary on the east side of the Gulf of St. Vincent. The white line crossing the lower right of the image was a contrail from a commercial jet aircraft.

none in the Alboran Sea. Was this the result of the turbulence from the Gibraltar solitons? Or does the Alboran Sea have some other dynamic action that precludes the formation of spiral eddies; that is, were we to learn the generating forces of the spirals in the first place?

Throughout the next 12 years, there was no certain answer to those questions. We finally concluded that the solitons moving through the Alboran Sea were too energetic to permit the formation of spiral eddies. Beginning with the flight of Shuttle Endeavor in May 1996, that conclusion was shown to be erroneous by a series of outstanding photographs of the eastern half of the Alboran Sea. From just west of the longitude of Cabo de los Muertos, spiral eddies, intricately interwoven, were observed cascading into the western Mediterranean, or vice versa (see photo, p. 40). To the west, to the approaches to the Strait of Gibraltar, none but the large-scale turbulence of solitons seems present.

Suloys: The Strangest Waves of All

For centuries, seamen have described lines of unusual and chaotic waves that extend across the ocean's surface. Sometimes curved, in other cases straight or in irregular "globby" bands, the state of the sea is of furious, precipitous, steep waves.

The first published descriptions of chaotic wave-lines were by Matthew Fontaine Maury in his 1857 edition of *The Physical Geography of the Ocean.* Maury gleaned the information from the thousands of ship logs available to him in the archives of the U.S. Naval Observatory. In every case, the state of the sea was so unusual in the experience of the ship's master, that the log entries were in great detail.

Such chaotic waves were encountered in every sea and ocean and in every season, and although the wave heights, widths, and lengths of the zones differed (some extended from horizon to horizon), the common denominators were winds of speeds less than 15 knots, and a rather mild sea. There was usually an intense hissing, roaring sound from the wave line, audible from distances of several kilometers. Of course, those were the days of sailing ships, with little extraneous sounds to mask that of the waves. Even so, some witnesses have compared the sound with that of a passing train, or the sounds from busy Abbey Road in London.

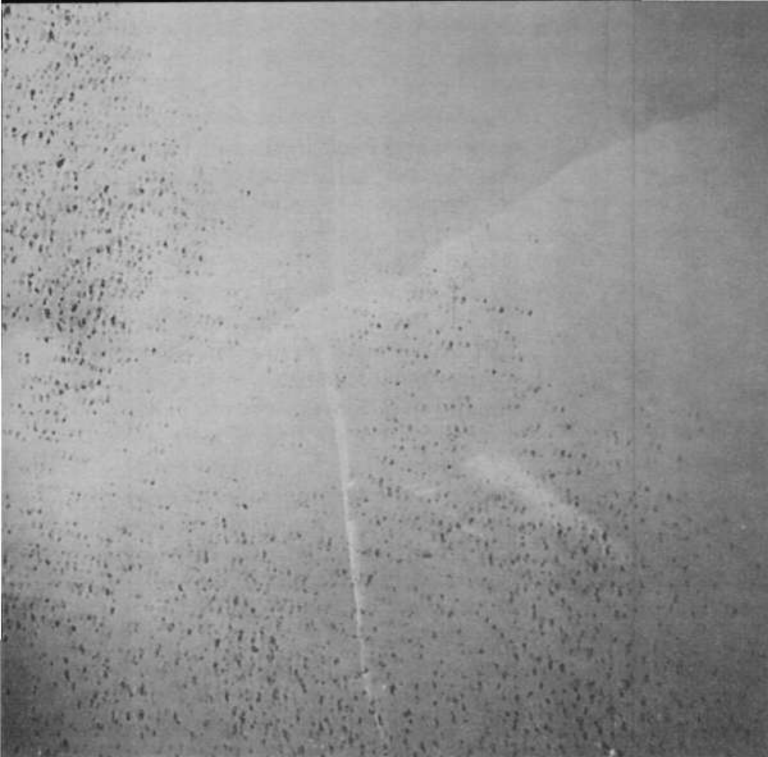
During mild, moonlit nights, conditions may permit wave lines to be easily observed. Such was the experience of Dr. Paul Scully-Power in the Tasman Sea while cruising through a dead calm in May 1975, aboard *HMAS Kimbla.* On the bridge at 0100 hours, he was startled by a broad, moonlit band of white ruffled water, stretching across the ship's course as far as he could see in either direction. On his request, the ship was stopped immediately in the middle of the choppy water.

The *Kimbla* has a length of 50 meters; the wave-line's width was less than the ship's length. Paul quickly set about launching expendable bathythermograph probes (XBTs), one after another. He managed to obtain 20 measurements of temperature to depths of 200 meters before the ship drifted out of the wave line.

At first glance, the continuous temperature traces appeared to indicate chaotic temperature inversions, ranging from 0.4°C through depths of a few centimeters, to those of 2°C+, extending through tens of meters. When the depths of the major inversions were plotted against time, however, it was clear that the temperatures defined a cluster of internal waves, less than 50 meters wide and extending to the greatest depths of the probes: 200 meters!

No further measurements were possible because of the demanding cruise schedule. (In addition, both the captain and Scully-Power rather lost interest when they decided that the interminably long line of white ruffled water was not a dump from a Swan Lager tanker.) Nonetheless, the data taken that night in the Tasman Sea make up the only definitive set taken within a chaotic wave line.

Of more than casual interest in this regard is a 1983 Japanese report of "a mysterious underwater acoustic effect" associated with "siomes" and distinct from conventional surface waves. As a chaotic wave line is approached, one would expect an intensification of ambient noise over that from surface waves. After all, the chaotic wave action is far greater within than outside—great enough to "bang and thump the hull to



Shearing suloy on the boundary of the southerly flowing current of Mozambique Channel, from the Shuttle Discovery, Aug. 16, 1985, at 190 nautical miles.

where I feared for the planks," as stated in more than one of the log books in Maury's hands.

If the chaotic "siomes" in the open ocean extend to depths of 200 meters, with the degree of turbulence measured by Scully-Power from the *Kimbla,* they possibly represent acoustic discontinuities as substantial as those in meso-scale eddies. Any knowledge of their generation, distribution, and life histories is clearly more than academic.

Actually, little more is understood about the nature of chaotic wave-lines than was known in the early 1980s, other than their distribution. Russian oceanographers have done the most work on this strange state of the sea, giving it the name of "suloy." The fullest description of suloys was made by the late Dr. Konstantin Fedorov in his 1983 book on *The Physical Nature and Structure of Oceanic Fronts.* In it, Fedorov documents the regions of the oceans in which suloys are most often encountered, and the variety of ocean conditions under which suloys may occur, such as tides, a convergence of currents, at oceanic fronts, or atop internal waves. "Wherever," he notes, "the dynamics of the near-surface ocean cause a convergence, there is a suloy."

Tidal suloys are readily explained, because they occur when strong tidal currents enter the shallow water of narrow straits. A line of precipitous waves, a suloy, is formed at the front of the tidal surge as it meets, and converges with, the surface wind waves. The precipitous chaotic waves in suloys may attain heights of 5 m (see photo, p. 41). West of San Francisco's Golden Gate, waves in the Point Bonita suloy can become so intense that even moderate-size ships have required more than one attempt to sail through the roaring wave line.

Suloys arise also where the strong discharge from major rivers converge on waters of the coastal ocean. Such features have been observed on several occasions by astronauts in

Continued from page 39

lands are bright and sharp. In the next instant, they recognize whitecaps and foam streaks on the sea.

Visual observations and photography of whitecaps are clearly not suitable to learn the extent to which they cover the world's sea surface at any given time. Yet, that knowledge is key to the determination of wind speeds and directions from Earth-orbiting, satellite-borne microwave scatterometers. Whitecaps and foam greatly influence the microwave emissivity of the ocean. The magnitude and variability of this emissivity change is not yet resolved.

"We continue to observe 'corduroy' and 'herringbone' seas in every part of the ocean where the Sun's glitter gives us a good look at the surface," reported Skylab astronauts, Cols. Gerald Carr and William Pogue, and Dr. Edward Gibson, in January 1974, indicating their ease in observing major ocean swell patterns. The "corduroy" seas are the result of parallel swell, while the "herringbone" seas are the result of swell crossing each other at oblique angles.

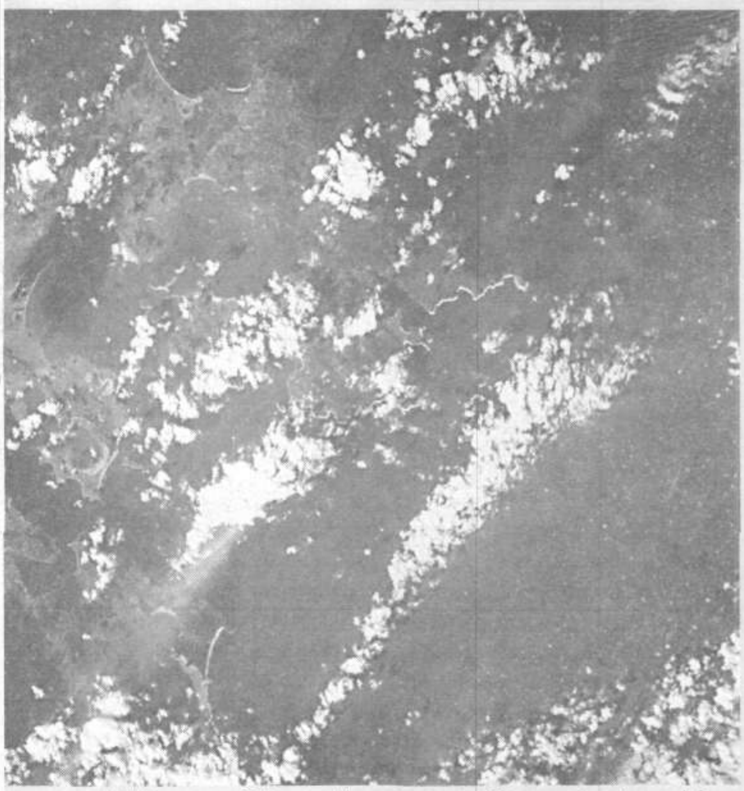
Ocean Swell. When wind waves leave the area of generation, the sea ceases to be random and the dominant wave period and direction of propagation take over. The sharp peaks of wind-waves flatten, the height decreases, and a regular pattern of parallel crests appears as the waves are transformed into swell. As the swell travel onward—through thousands of kilometers of ocean if no land intervenes—the longest lengths and greatest periods, predominate. Crest lengths may grow to thousands of meters and become extraordinarily parallel to each other. These are the corduroy seas visible from space in the great expanses of the oceans (see photo, p. 43, bottom left).

Swell from more than one storm-generating region, or originating simultaneously from stormy oceans in the Northern and Southern hemispheres, may eventually intersect each other. In such parts of the ocean, commonly near the Equator, the intersecting swell form the "herringbone seas" that were observed first by the Skylab-4 crew, but subsequently on innumerable occasions by astronauts aboard the Space Shuttle (see photo, p. 43, top right).

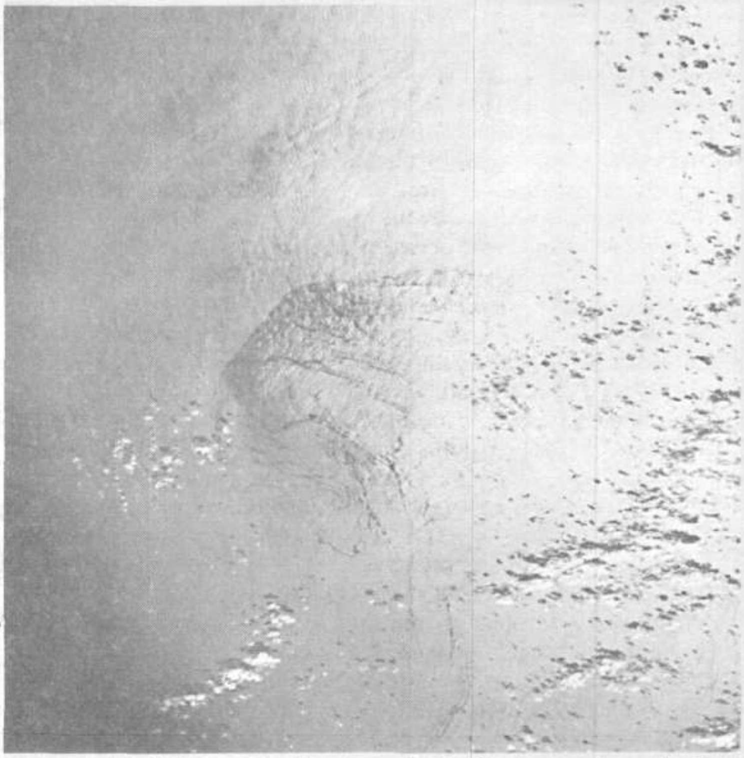
Breakers, Surf, and Refraction. When a wave approaches the shore, its crest moves faster than the trough, responding to the friction exerted by the sea floor. At the moment when the velocity of water particles in the crest exceeds the forward speed of the wave form, the wave "breaks." The crest overtakes the trough at this stage, the leading slope of the wave becomes steeper than the trailing side, and the top of the wave cascades down the steep slope, forming the "surf zone."

Waves tend to form "plunging breakers" where bottom slopes to the beach are relatively steep. These are the spectacular "curling" breakers, in which the crests literally collapse onto the steep, forward slope of the breaking wave. Where better to see these crashing giants than at Sunset Beach on the north shore of Oahu in winter? They are the professional surfers' joy; the amateurs' continuous "hang ten" disasters (see photo, p. 43, bottom right).

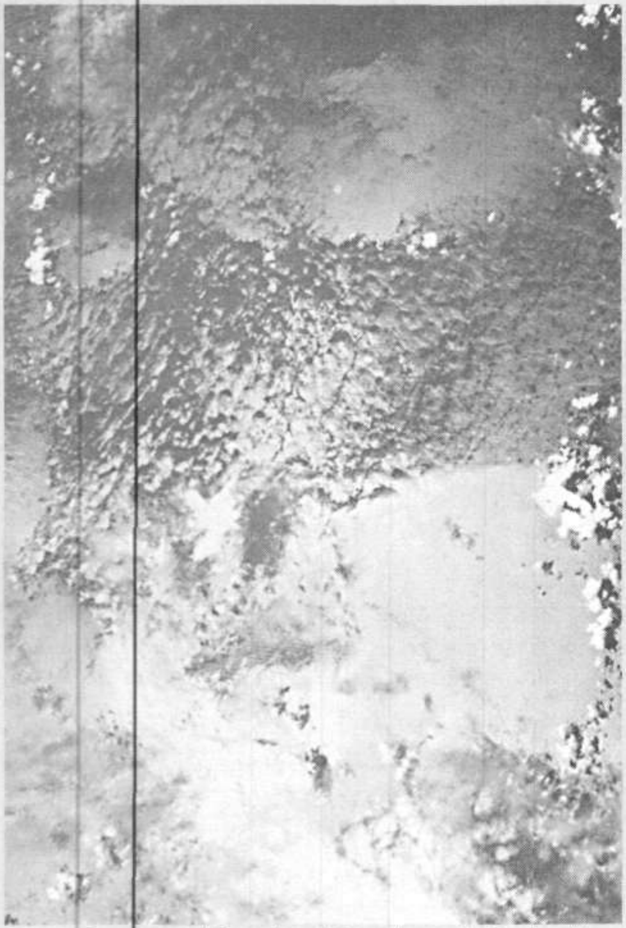
Continued on page 45



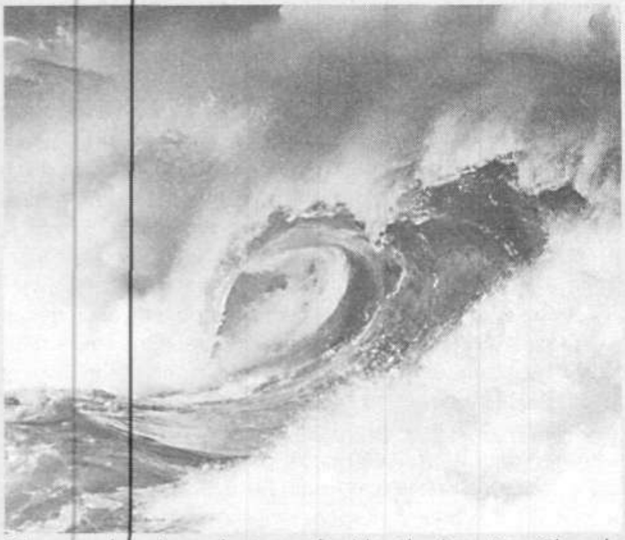
Whitecaps off the southeast coast of Tasmania, viewed from the flight deck of the Shuttle Endeavor, Dec. 6, 1998.



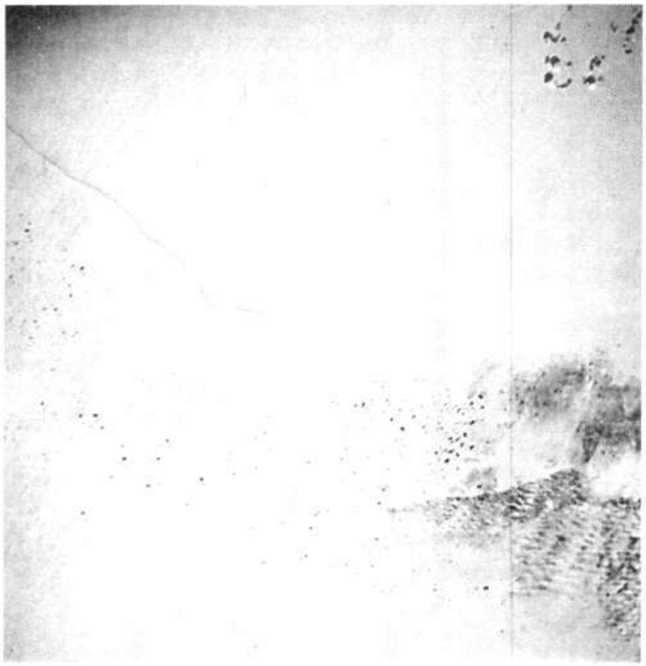
Parallel ocean swell, equatorial Pacific, as seen from the Shuttle Challenger, Nov. 1, 1985.



Sea-surface "scars," from the vicious down-drafts of collapsing, towering cumulus clouds, provide a smooth surface in which crossed ocean swell were readily observed from the Shuttle Discovery, Nov. 25, 1989.



Plunging breaker, photographed by the late Ron Church, Scripps Institute of Oceanography, on the north shore of Oahu, Hawaii.



First observation of an open ocean suloy, at 4.5°N, 134°W, photographed by the crew aboard the Shuttle Discovery, Oct. 1, 1988.

the Rio de la Plata Estuary in the waters just south of Montevideo, Uruguay. In those waters, the view being aided by the muddy red water of the Rio de la Plata, the surge of the river's discharge on the falling tide can be great enough that the suloy is soon deformed into a series of eddies and whirlpools.

Of most interest to the oceanographer are the suloys of the open ocean. There they are associated with ocean fronts, especially fronts that mark the convergent boundaries of ocean currents. It is not clear whether the density difference across the front is necessary to the formation of a suloy, but it is certain that the shear between the currents is significant (see photo, p. 42). The relative change in current speed and direction across the boundary effectively determines the extent of wave interaction at the convergence. This interaction, and the resulting suloy, will be observable, of course, where wind waves are not intense; that is, when winds are blowing at less than 15 knots.

Georgiey Grechko's 'Equator'

In 1980, while orbiting aboard the Soviet's Salyut "6" space station, Cosmonaut Georgiey Grechko made a routine report to the USSR's Mission Control:

> We're over the Indian Ocean. There are so few clouds that we can see nearly from one side of the ocean to the other. And, right in the middle, extending east-west, we can see the bright line of the Equator.

The Soviet space program was in its "heyday." They were launching three to four satellites each month, had three to four classified satellites in orbit at all times, were preparing sophisticated environmental spacecraft loaded with microwave sensors, and had receivers that were regularly downloading data from all U.S. weather satellites. The USSR manned space program maintained basically continuous communications with their cosmonauts, through shipborne tracking stations distributed around the world's oceans.

Grechko's disclosure of the ready observation of the "Equator" by the Salyut crew was transmitted in real-time, therefore, through the tracking ship in the Indian Ocean. Such communications were not secure, so it was not long before the oceanographic world learned of the "visible Equator."

The reaction was laughter, not only in Mission Control, but among all of us who were privy to the science discussed from Salyut. Neither Paul Scully-Power nor I had reached the point of considering the possibility of observing anything significant other than "those weird corkscrew eddies." That Grechko might have observed a long suloy along the edge of the equatorial current system was nowhere near our ken, at that time.

In retrospect, we thought that Fedorov might have recognized the possibility of an equatorial suloy. After all, he knew more about the strange waves than any other oceanographer; he was about to "write the book!" Yet, in a later conversation with Fedorov, he admitted that he had not even considered the idea. In a meeting with Georgiey Grechko, in 1987, during an international geophysical meeting in Vancouver, B.C., Paul and I queried him about "his observation of the Equator." He was reluctant to commit himself, even after we pointed out to him that it was no doubt an equatorial suloy. "A what? Never heard of it," he said.

Equatorial Suloys

Serendipity is one the nicest, most appreciated companions of any scientist, or explorer. It is rare that anything is ever discovered, or that any theory ever becomes fact, without serendipity being along for the ride.

And, so it was for the STS-26 flight of the space Shuttle Discovery, the flight that was the "Return to Space" two and a half years after the devastating Challenger accident. Aboard would be a veteran crew: four military and one Ph.D. astronomer. Their primary task was a good, successful, clean mission. During the four days, in a 28.5° inclination orbit, they would deploy a tracking and data relay and a communication satellite, and conduct a number of on-board experiments, and there would plenty of time to observe the Earth.

The pilot, Lt. Col. Richard Covey, USAF, would be on the flight deck most of the time and able, therefore, to view the Earth's surface rather continuously. Dick knew the story of Hoot Gibson, and his crew on the STS-61C mission when, after using up all of their film, they had spent a full day glued to the window unsuccessfully looking for spiral eddies at the Equator. During STS-26, the Sun angle and ocean viewing over the tropical Pacific would be perfect to observe and photograph any spiral eddies that existed. With two Hasselblad cameras, each with a different focal-length lens, Dick Covey would be ready constantly.

After a perfect four-day mission, the crew was back in Houston on Oct. 3, 1988. I was there the next morning going through the photography and encountering the first-ever images of open-ocean suloys, stretching for hundreds of miles across the equatorial Pacific. It was difficult to believe

Continued from page 42

"Spilling breakers," in which the water from the crest slides down the inclined plane of the forward slope, are the prevalent surf where the sea floor slopes gently to beach over distances of a few hundred meters. The breaking action is far gentler than that of the "plunging breaker," giving the surfer, canoer, and beginner a long, slow "tour" as they approach the beach. Such is the surf off the famous Waikiki Beach of Honolulu, where tourists and beach boys alike enjoy surfing with relative ease.

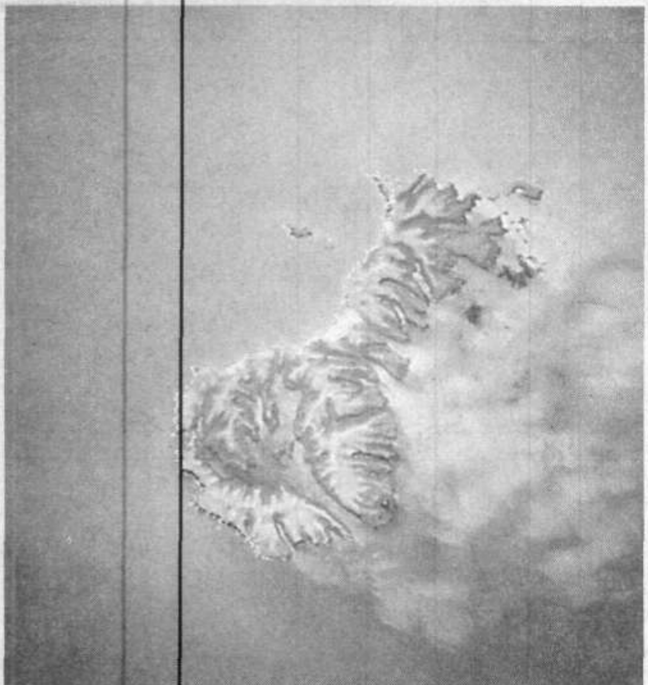
Refracting Waves. When gravity waves reach water that is shallower than half their wavelength, and their crests are not parallel to the contours of the sea floor, they will begin to refract (bend). This action comes about as the forward speed of those portions of the waves in shallower water slow in respect to those remaining in deeper water. While the wave frequency stays the same, the amplitude and the lengths change substantially. Approaching a straight shoreline over a gently shoaling shelf, the wave crests continue to refract, until they break in the surf zone along a line parallel to the beach.

Waves approaching coastal headlands are in deep water almost to the shore, where they strike the cliffs with great force (see photo, top right). The wave crests do refract along either side of a headland, causing diverging wave paths in the embayments adjacent to the capes. The consequence is that most of the wave energy is concentrated at the headlands and dissipated along the beaches to the side. There is, therefore, a lot of turbulence and mixing, and crashing waves at sea cape (see photo, bottom right).

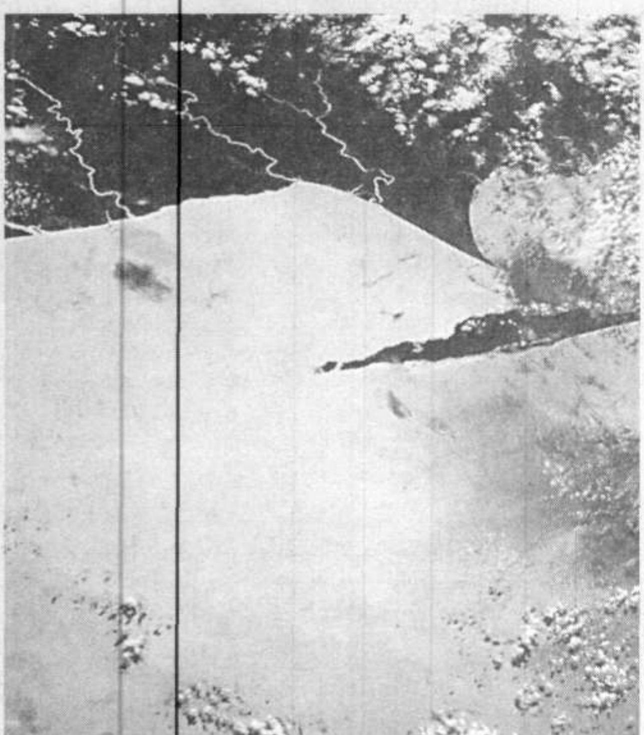
(As an aside, headlands are good places to put sewer outfalls so that the discharge is distributed a rapidly as possible. Waters in embayments are just the opposite; there, mixing and wave action are mild leading to deposition of materials rather than distribution. As you might guess, however, most sewage disposal locations have been built in quiet bays; not at turbulent headlands.)

Submarine canyons that indent the shelf, with their heads close to the shore, create refraction patterns that are often disconcerting to the beach inhabitants. The deep water in the canyons permits the waves to approach the beach with barely diminished forward speeds. On either side of the canyon, where the sea floor is shallower than that in the canyon, the wave fronts refract away from the canyon. The energy is concentrated at the shore opposite the canyon's head, therefore, and dissipates along the beaches to either side.

Those who are unaware of the location of a canyon have built houses or piers on shore near its head. It is a common situation in southern California, where such owners often are surprised to find their house, or pier, under attack by destructive waves, while rather benign breakers strike the beaches just a few hundred meters away.



The huge surf crashing against the 600-meter cliff of the western coast of the Auckland Islands, was easily observed by the crew aboard the Shuttle Endeavor, Jan. 26, 1998.



Refracting ocean swell and currents around the southern tip of the island/headland Nosy Boraha on the northeast coast of Madagascar were visible to the crew of the Shuttle Atlantis, May 20, 1997, at 160 nautical miles altitude.

my eyes, but the photographs were outstanding, easily examined under a high-powered lens (see photo, p. 44).

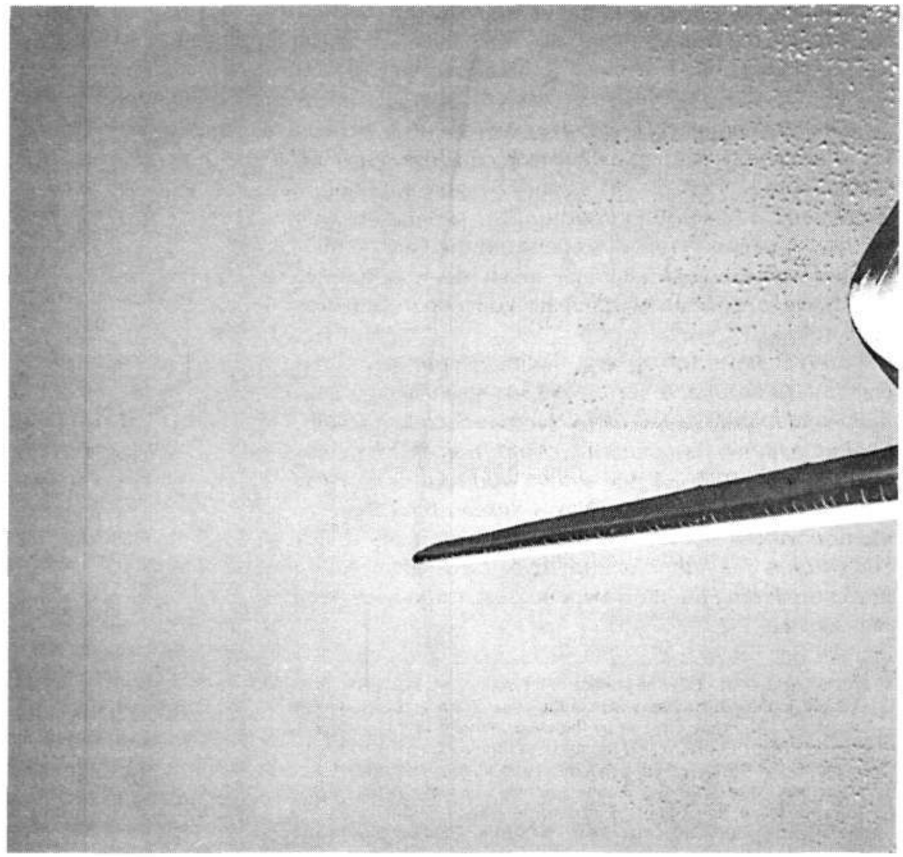
Excited, I called Paul Scully-Power in New London, Conn., where he was doing submarine acoustic research. "Dick Covey got 'em," I exploded, "No, not eddies at the Equator, but huge, long solitons. They're the acoustic barriers in the tropics."

Paul's response, "Good on ya, mate," was indicative that a problem had an answer.

About to leave for lunch, I met Dick Covey and the mission commander, Capt. Rick Hauck, as they were coming in to view the photos to prepare for their press conference at the end of the week. As I shook hands with Dick, he began apologizing:

> Gee, Bob, I tried. I looked at that tropical Pacific Ocean for hours. It was as quiet, as flat as a board. Nothing! I took a lot of pictures, but I just must have missed anything good.

Before I could say a word, Rick broke in:



A continuous series of equatorial open-ocean suloys, between 1° and 3°N in the central Pacific, viewed from the flight deck of the Shuttle Atlantis, August 1992.

> I'm telling you, Bob. Both Dick and I spent a lot of time watching that ocean. The Sun's glitter pattern was perfect. But, I guess Hoot Gibson and his guys were right, there are no spirals near the Equator. It was just flat. No action.

I just grinned. "Gentlemen. First, congratulations on a great flight. Now, come with me into my "photo lair."

Cranking through the rolls of film over the light table, I said, quickly,

> You can go through the rolls at you leisure shortly, and you got some great stuff. First, though, let me show you the first photos ever of an ocean feature for which we've searched for years.
>
> O.K. Here's your flat calm tropical Pacific. See that little line. No, it's not a scratch on the film, it is the visible response of an open-ocean suloy. Covered by these five photos, the wave-line was more than 500 miles long and about as close to being parallel to the Equator as I can judge. From the the preliminary flight data, it started about 3° north of the Equator near the Date Line and you tracked it to within 1.5° north.

"Holy Cow," was the response from Dick Covey, as he looked at the photos. "Man, I've got to tell you that I never saw those things; not at all." Rick's comment was the same.

"Ah, yes." said I, "Serendipity rides along once again."

> I'm not surprised that you didn't see them. All of the suloys ever seen from space have been around islands, in embayments, or straits. It's just the same as Dave Leestma not seeing hundreds of spiral eddies when he was looking for ships' wakes. He was geared to wakes, so saw no eddies even though they were visible. You were prepared to see eddies, and there were none.

We discussed the thought of naming them "Covey's Shears," but decided that even though it was not as good as having a freeway named after you, such as, the "John Young Expressway" in Florida. It would be difficult to take your family on a visit to a "Covey Shear."

Once we learned that open-ocean suloys did exist, and how they appeared from space, then observations came from every Shuttle crew that flew over the tropical ocean at times when the Sun's glitter pattern was suitable for viewing. Some of the best came from the crew of STS-46, flying in the Atlantis in August 1992 (see photo, above). Although they had a number of tasks that were technically demanding, there were three avid Earth observers aboard: the mission commander, Col. Loren Shriver, and mission specialists Claude Nicollier and Marsha Ivins.

With real-time information also coming from the on-board video, the location of the suloy was quickly sent to Honolulu where there was a NOAA ship ready to sail on a tropical scientific cruise. It took the ship four days to reach, locate, and examine waters in and around the suloy. Although the ship did not encounter an extraordinary wave-line, the upper ocean on either side had both color, biological, and temperature differences.

One gets the feeling that suloys are about as ephemeral but as ubiquitous as spiral eddies, the conclusion reached by Commodore Maury 150 years ago. The more we understand the dynamics of suloys and other near-surface ocean phenomena, the more we will understand the Earth's environment. If we keep working long enough, doing honorable research, we might learn what's really going on in, and around, the Earth.

Robert E. Stevenson, an oceanography consultant based in Del Mar, California, trains the NASA astronauts in oceanography and marine meteorology. He was Secretary General of the International Association for the Physical Science of the Oceans from 1987 to 1995, and he worked as an oceanographer for the U.S. Office of Naval Research for 20 years. A member of the scientific advisory board of 21st Century, *Stevenson is the author of more than 100 articles and several books, including the most widely used textbook on the natural sciences.*

Notes

1. The Sun's reflection from the surface of the sea, called Sun glitter, is a valuable tool in the visual observation of the ocean from space. Sea slicks, either caused by surfactants or by the water moving with the wind, reflect brightly, whereas water flowing against the wind, resulting in choppy waves on the sea's surface, has a diffuse, dull reflection. These reflective differences are easily seen, and they photograph well. On the edge of the Sun's reflection, the golden colors change to blues. In this part of the glitter pattern, smooth water has a dark color, and the roughened water has a light blue cast.
2. For the author's story of the discovery of spiral eddies, see "Spiral Eddies: The Discovery That Changed the Face of the Oceans," *21st Century*, Fall 1998, p. 58.

Selected References

W. Alper and E. Salusti, 1983. "Scylla and Charybdis Observed from Space," *Geophys. Res.*, Vol. 88.

J.R. Apel, J.R. Holbrook, A.K. Liu, and J.H. Tsai, 1985. "The Sulu Sea Internal Soliton Experiment," *J. Phys. Oceanogr.*, Vol. 15.

L. Armi and D.M. Farmer, 1985. "Surface Manifestations of Internal Hydraulics of Gibraltar Straits," *EOS, Transactions Am. Geophys. U.*, Vol. 66.

———, 1986. "The Internal Hydraulics of the Strait of Gibraltar and Associated Sills and Narrows," *Oceanol. Acta*, Vol. 8.

V. Artale, D. Levi, E. Salusti, and F. Zirilli, 1984. "On the Generation of Internal Solitary Waves," *Il Nuovo Cimento*, Vol. 7.

G.I. Barenblatt, I.A. Leikin, and A.S. Kazmin, 1985. "Rip in the White Sea," *Dokl. Acad. Sci USSR*, Vol. 281.

A.Y. Basovitch, 1979. "Transformation of the Surface Spectrum by the Action of Internal Waves," *Fizika. Atm. Okean.*, Vol. 15.

R.L. Bernstein, P. Scully-Power, R.E. Stevenson, B. Wannamaker, and D. Roe, 1980. "Combined Ocean Sensing Program of the Alboran Region," COSPAR/SCOR/IUCRM Symp. Ocean Fr. Space, Venice, Italy.

N.B. Bhosle et al., 1983. "Lipid Content in Surface Waters of Arabian Sea," *Indian J. Mar. Sci.*, Vol. 12.

V.M. Burdyugov and S.A. Grodsky, 1984. "Method of Estimating the Dispersion Relationship of Internal Waves by Sea Surface Images," in *Problemy Issledovaniya Okeana iz Kosmos, Ed. B.A. Nelepo, (Sebastopol: MGI, Acad. Sci. Ukrainian SSR).*

R.E. Cheney and R.A. Doblar, 1982. "Structure and Variability of the Alboran Sea Frontal System," *J. Geophys. Res.*, Vol. 87.

R.K. Chereskin, 1983. "Generation of Internal Waves in Massachusetts Bay," *J. Geophys. Res.*, Vol. 88.

A. Defant, 1932. "Die Gezeiten und inneren Gezeitenwellen des Atl. Ozeans," *Meteor. Werk.*, Vol. 7.

R.S. Dietz and E.C. LaFond, 1950. "Natural Slicks on the Ocean," *J. Marine Res.*, Vol. 9.

R. Dorerestein, 1951. "General Linearized Theory of the Effect of Surface Films on Water Ripples," *Konink. Ned. Akad. Wetenschap. Proc.* B54.

G. Ewing, 1950. "Slicks, Surface Films, and Internal Waves," *J. Mar. Res.*, Vol. 9.

D. Farmer and J.D. Smith, 1978. "Nonlinear Internal Waves in a Fjord," in *Hydrodynamics of Estuaries and Fjords*, Ed. J.C.J. Nihoul (Amsterdam: Elsevier Oceanog. Ser., No. 23).

K.N. Fedorov, 1976. "Space Observations of Oceanic Internal Waves," *Okeanologiya*, Vol 16.

———, 1983. *The Physical Nature and Structure of Ocean Fronts* (Leningrad: Gidrometeoizdat).

K.N. Fedorov and A.I. Ginsburg, 1986. "Phenomena on the Ocean Surface by Visual Observations," *Okeanologiya*, Vol. 26.

———, 1992. *The Near-Surface Layer of the Ocean* (Netherlands: Konink), trans. M. Rosenberg (first pub. in Russian, 1988).

A.I. Ginsberg and K.N. Fedorov, 1984. "Evolution of Mushroom-like Currents in the Ocean," *Dokl. Acad. Sci., USSR*, Vol. 276.

G.M. Grechko, G.A. Grishin, and G.A. Tolkachencko, 1981. "Observation of Visible Manifestations of Ocean Dynamics from Aboard the Salyut-6 Orbital Station," *Issled. Zemli Iz. Kosm.*, No. 4.

A. Griffa, S. Marullo, R. Santoleri, and A. Viola, 1986. "Internal Nonlinear Tidal Waves Generated at the Strait of Messina," *Cont. Shelf. Res.*, Vol. 6.

T.L. Howell and W.S. Brown, 1985. "Nonlinear Internal Waves on the California Continental Shelf," *J. Geophys. Res.*, Vol. 90.

J.D. Isaacs, 1962. "Note on the Association of Cumulus Clouds and Turbid Water," *J. Geophys. Res.*, vol 67.

H. Lacombe, 1990. "Water, Salt, Heat, and the Wind in the Mediterranean," *Oceanus*, Vol. 33.

T. Laevastu, 1960. "Factors Affecting the Temperature of the Surface Layer of the Sea," *Soc. Sci. Fennica. Commentationes Phys. Math.*, Vol. 25.

E.C. LaFond, 1959. "Sea-surface Features and Internal Waves in the Sea," *Indian J. Meteor. Geophys.*, Vol. 10.

P.E. LaViolette and R.A. Arnone, 1983. "Regional Circulation in the Area of the Strait of Gibraltar as Defined by Space Shuttle Photographs," *EOS, Trans. Am. Geophys. U.*, Vol. 66.

A.K. Liu, J.R. Holbrook, and J.R. Apel, 1986. "Nonlinear Internal Wave Evolution in the Sulu Sea," *J. Phys. Ocean.*, Vol. 15.

M.F. Maury, 1858,. *The Physical Geography of the Sea and Its Meteorology* (New York: Harper and Bros.).

J.W. Miles, 1957. "On the Generation of Surface Waves by Shear Flows," *J. Fluid Mech.*, Vol. 3.

W.H. Munk, P. Scully-Power, and F. Zachariasen, 1987. "Ships from Space," *Proc. Roy. Soc. London*, A412.

F.N. Nares, 1872. "Investigation of Currents in the Strait of Gibraltar," *Proc. Roy. Soc. London*, Vol. 20.

A.R. Osborne and T.L. Burch, 1980. "Internal Solitons in Andaman Sea," *Science*, Vol. 208.

A.R. Osborne, A. Provenzale, L. Bergamasco, and P. Trivero, 1985. "Measurement of Periodic Nonlinear Surface Wave-trains Approaching the Coast and Soliton Fission," *Rapp. Proc. Verb., CIESMM*, Vol. 29.

B. Saint-Guily, 1972. "On the Response of the Ocean to Impulse," *Tellus*, Vol. 24.

H. Sandstron and J.A. Elliot, 1984. "Internal Tide and Solitons and the Scotian Shelf: A Nutrient Pump at Work," *J. Geophys. Res.*, Vol. 89.

G. Schott, 1928. "Die Wasserbewegungen im Gebiete der Gibraltarstrasse," *J. Cons. Intern.*, Vol. 3.

P. Scully Power, 1986. *Navy Oceanographer Shuttle Observations, STS-41G Mission Report* (New London: NUSC Tech Doc. No. 7611).

———, 1985. "Ocean Dynamics: Views from Space," *EOS Trans. Am. Geophys. U.*, Vol. 66.

R.E. Stevenson, 1974, "Observations from Skylab of Mesoscale Turbulence in Ocean Currents," *Nature*, Vol. 250.

———, 1977. "Huelva Front and Malaga, Space, Eddy Chain as Defined by Satellite and Oceanographic Data," *Sond. Deutchsen Hudrogr. Zeit.*, Vol. 30.

———, 1989. *Oceanography from the Space Shuttle*, (Boulder, Colo.: NCAR Publ.).

———, 1997. "The Ocean Is Full of Nonlinear Structures," *Exec. Intell. Rev.*, Vol. 24.

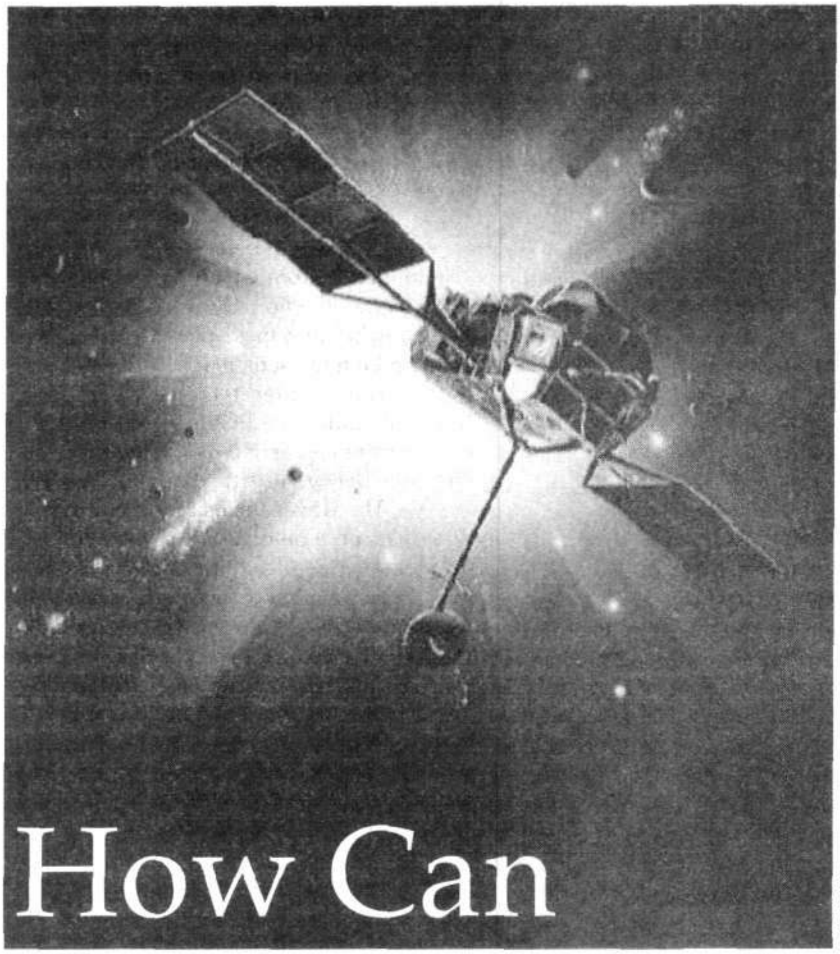
———, 1998. "Spiral Eddies: The Discovery That Changed the Face of the Oceans," *21st Century Science & Technology* (Fall).

R.E. Stevenson and P. Scully-Power, 1977, "Worldwide Ocean Fronts from Satellites," Chapman Conf. Oceanic Fronts, *Trans. Am. Geophys. U.*, Vol. 58.

R.P. Trask and M.B. Briscoe, 1983. "Detection of Massachusetts Bay Internal Waves by Synthetic Aperture Radar on SEASAT," *J. Geophys. Res.*, Vol. 88.

M. Uda, 1938. "Researches on 'Siwome' or Current Rip in the Seas and Oceans," *Geophys. Mag.*, Vol. 11.

A.G. Zatsepin, A.S. Kazmin, and K.N. Fedorov, 1984. "Thermals and Visible Manifestations of Large Internal Waves on the Ocean Surface," *Okeanologiya*, Vol. 24.



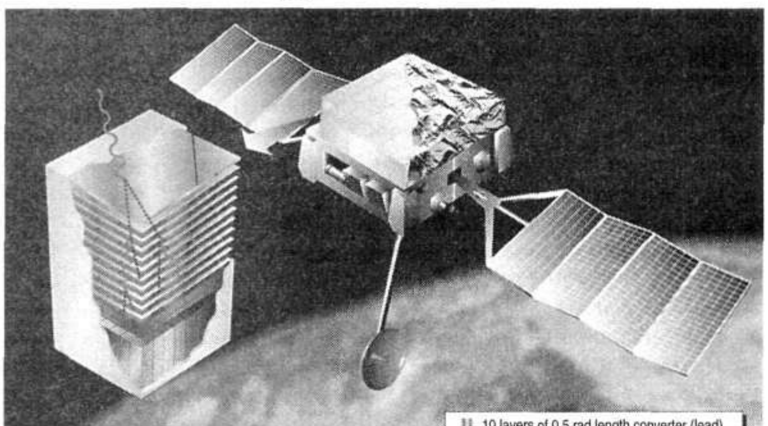
Artist's illustration of NASA's Compton Gamma-Ray Observatory with solar array panels fully extended and high gain antenna deployed, highlighted against an energy burst.

NASA/TRW

How Can Gamma-Ray Bursts Be Explained?

by Lothar Komp

The direction in which astronomers are looking for an answer may have problems as great as the direction they have ruled out.



NASA

NASA's Gamma-Ray Large Area Space Telescope (GLAST), which is to go into orbit early in the 21st century.

In 1967, the Vela reconnaissance satellites of the U.S. Defense Department made an astonishing discovery. Four years earlier, an agreement had been reached banning nuclear weapons testing in the atmosphere. The reconnaissance satellites were supposed to monitor Soviet compliance with the agreement. It was conceivable that the Soviets could use near-Earth orbits for nuclear tests. Since the race to the Moon had just entered its decisive phase, that was an unsettling possibility. If there were nuclear explosions, their gamma-ray flashes would be visible for thousands of kilometers. The Vela satellites did pick up gamma rays, but they seemed to be coming from all possible directions! Had the Soviets already conquered the entire solar system, and were they exploding one atom bomb after another? The existence of the mysterious gamma-ray bursts was kept classified for six years. In 1973, when there was no longer any suspicion that the Soviets were behind these bursts, the observations were declassified and made available for astrophysical research.

Twenty-Five Years of Research

More than 2,000 gamma-ray bursts have been detected by satellites over the past 25 years. Since the launching of NASA's Compton Gamma-Ray Observatory (CGRO) in 1991, its detectors have registered an average of one burst per day. The bursts seem to be randomly distributed throughout the heavens, and never appear in the same place twice. Because they are neither close to each other, nor mobile, multiple detections cannot be attributed to the same source. The bursts last anywhere from one-hundredth of a second to a few minutes, but seldom more. They are always the brightest gamma-ray feature in the sky.

From 1967 until recently, a hundred different models sought to explain the origin of these gamma-ray bursts. Because of the remarkable isotropy of the phenomenon (the bursts appear in all directions, without preference) the proposed distance of the burst sources was repeatedly pushed out: from near-Earth space, to the Oort Cloud, then into the interstellar surroundings of the Solar System, then out into an extended spherical halo of our galaxy.

All of these models collapsed over the course of 1997, thanks to the detections of the Italian-Dutch X-ray satellite BeppoSAX, which has a gamma-ray detector on board. This new evidence pointed to burst sources being billions of light-years away. That would make them the most powerful sources of radiation, at the moment of their eruption, in the region of those billions of galaxies that most astrophysicists call "the universe." What makes this phenomenon more puzzling, is that according to relativity theory, a formation that erupts in fractions of a second cannot be larger than the distance light can travel in the same time. Otherwise, the disparate parts of the process could not be in communication, and would not "agree" on the timing of the eruption. Accordingly, at least some of the gamma rays must be generated within a radius of about 100 kilometers—tiny compared to the size of a common star. Even for astrophysicists, who are accustomed to superlatives, these results are difficult to digest.

The Heavens in Gamma Light

The Earth is constantly bombarded by extremely energetic cosmic radiation, but the atmosphere blocks out all but a tiny fraction of it. When cosmic rays strike the outer atmospheric layers, they produce showers of secondary particles that are able to cut through the atmosphere, frequently disrupting radio transmissions. Cosmic radiation is thus best studied by probes above the atmosphere.

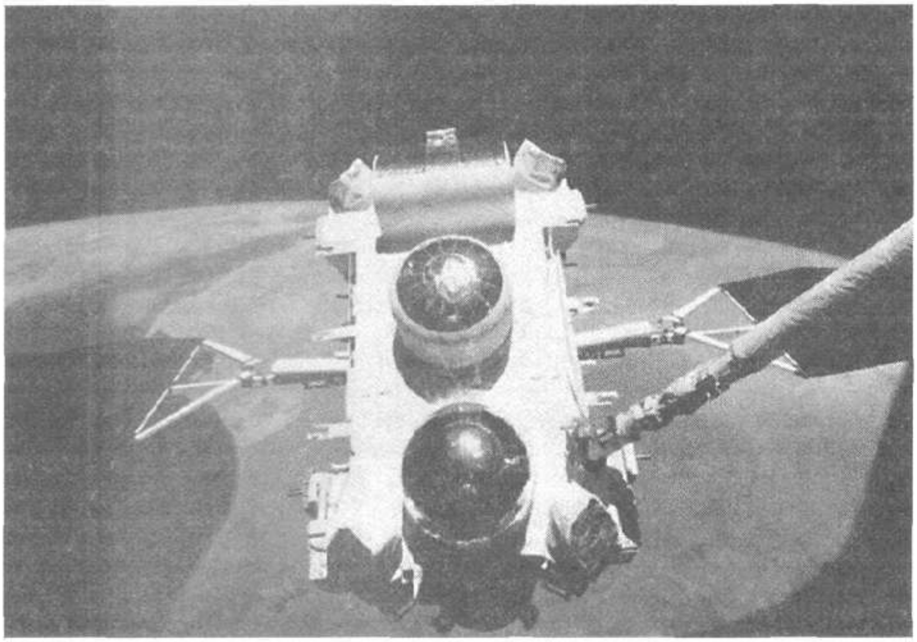
Cosmic rays are composed primarily of protons, helium nuclei, and electrons, with individual particles having energies of up to 100 billion gigaelectron volts (GeV). That is millions of times more energy than can be achieved using particle accelerators. The direction from which they hit the Earth discloses nothing about the direction of the source because, instead of moving in straight lines, these particles are thrown around by interstellar and intergalactic magnetic fields.

The situation is somewhat simpler in the case of the non-particle portion of cosmic radiation, that is, electromagnetic waves. Of course, with extreme energies (short wavelengths), the observable difference between particles and electromagnetic waves disappears. The waves deposit their energies on the Earth's atmosphere or on a detector in discrete portions (quanta). The larger the energy, the shorter the wavelength. Physicists do not use wavelength to characterize shortwave electromagnetic radiation; instead, they cite the characteristic energy of the quantum. The basic energy unit used is the electron volt (eV), as if the energy were that of a charged particle accelerated by a high current. When the energy of this radiation is more than 511 eV, it tends, under appropriate conditions, to generate "real" particles—pairs of electrons and their associated anti-particles, the positrons. Inversely, in the "pair destruction" of a particle and its anti-particle, electromagnetic radiation of at least 511 eV is generated.

The most energetic waves (shortest wavelengths) in the electromagnetic spectrum are called gamma radiation. The boundary with X-rays is set somewhat arbitrarily at the wavelength of one-hundredth of a nanometer, which corresponds approximately to one-tenth of an atomic diameter. While cosmic X-rays are absorbed by Earth's atmosphere at altitudes of more than 40 kilometers, gamma radiation is more penetrating. Extremely short wavelength gamma rays can reach the highest summits in the Himalayas. When gamma radiation reaches the tera-electron-volt (TeV) level, it produces cascades of secondary radiation through collisions with particles in the upper levels of the atmosphere. The electrons so produced are transmitted in the atmosphere faster than the speed of light. The electromagnetic shock-front thus generated, named after the Russian physicist Cerenkov, can be detected at the surface of the Earth. The 10-Meter Optical Reflector, the instrument of the Gamma-Ray Project of the Whipple Observatory near Tucson, Arizona, exploits this phenomenon. It observes cosmic gamma radiation with very low spatial resolution, of course, and with low sensitivity, on account of the background noise generated by cosmic particle radiation.

Gamma rays are produced by certain changes in the nucleus, and they are also capable of inducing such changes. For astronomical objects, one important spectral line in the gamma region is manifested, for example, in the radioactive decay of aluminum-26 to magnesium-26. Here the energy per quantum of radiation is 1.809 mega-electron-volts (MeV). Because aluminum-26 can only be produced in quantity by nuclear fusion under extraordinary conditions, such as in the process of supernova explosions, and because it also decays rapidly on the astronomical time-scale (half-life 714,000 years), the gamma sky at 1.809 MeV tells us where such processes have recently occurred.

The spectral line of radioactive aluminum was discovered only at the beginning of the 1980s by the U.S. HEAO-3 satellites. Since then, the gamma radiation of aluminum-26 in our skies has been found to be strongest along the band of the Milky Way, with a particular concentration toward the center of the galaxy. The estimated total volume of aluminum-26 derived from these observations, about two times the mass of the Sun, is much larger than one would expect from novae and supernovae. So there are, presumably, other sources as well.



NASA

The Compton Gamma-Ray Observatory, as it was deployed into orbit by the Space Shuttle in April 1991.

In addition to matter-antimatter reactions and nuclear processes, extremely strong magnetic fields may also contribute to the production of gamma radiation. These fields force electrons to travel in tight spirals, which excites the electrons to emit gamma radiation. This gamma radiation is not restricted to a specific wavelength, but is spread over a range.

The most important phenomena in the gamma heaven are:

• The remnants of supernovae. For example, the Vela and Geminga pulsars and the Crab nebula. The latter arose from a supernova observed by Chinese astronomers in the year 1054. These are the brightest continuous gamma emitters in the sky.

• The galactic center is, likewise, a strong, continuous emitter. This is all the more true for the nuclei of certain other galaxies, the so-called active galactic nuclei, which are, however, much farther away.

• The Sun is normally fairly dark in the gamma region, but brightens dramatically during some flare eruptions. Astronauts have to be protected against such emissions.

• The most numerous gamma sources within our galaxy are believed to be double stars orbiting each other at such close proximity that gas flows from one to the other.

• Regions in our galaxy in which stars are formed, such as the Orion nebula, also emit gamma radiation.

• Along the Milky Way there is diffuse gamma radiation, which cannot be assigned to particular sources, and is associated with the interstellar medium.

• After subtraction of all individual sources and the diffuse gamma radiation within the Milky Way, a considerably more diffuse residue remains, called cosmic gamma background radiation. The origin of this permanent, diffuse background is not known. It might be caused by an immense number of unresolved particular objects, such as active galactic nuclei. Another speculation supposes the presence of equal amounts of matter and antimatter in the cosmos, so that complete galaxies and groups of galaxies could consist of antimatter. At the regions of intersection of matter and antimatter, there would then be a process of continual pair destruction, and thus the production of gamma radiation.

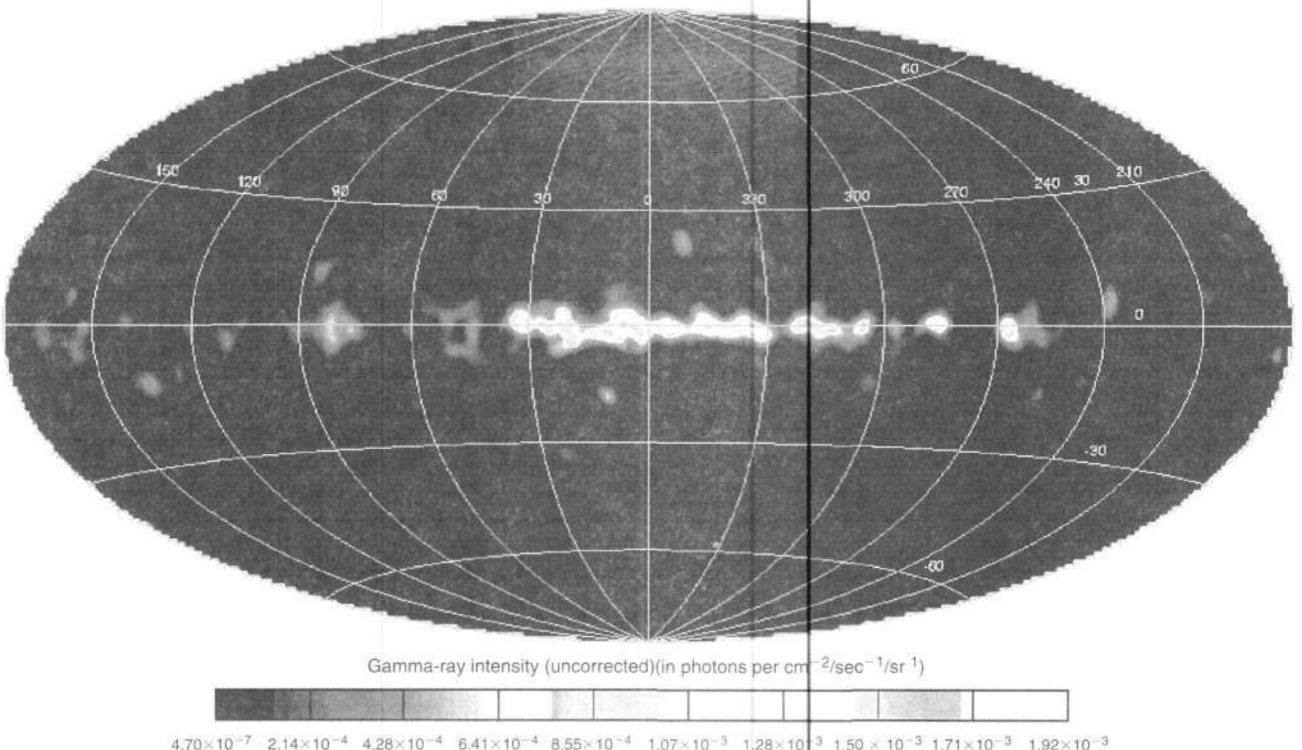
• Finally, there are the gamma-ray bursts, surpassing all other sources in brightness for brief moments.

The Beginnings of Gamma Astronomy

In addition to the inability of gamma radiation to penetrate Earth's atmosphere, gamma astronomers have to deal with another difficult problem: There are neither lenses nor mirrors for gamma rays. Now and then people do speak loosely about gamma "telescopes," but what they are talking about is always an array of gamma detectors. Crystals of sodium iodide or cesium iodide are often used, which are excited to emit light in the visible part of the spectrum when they are struck by gamma quanta (scintillation). Signal amplifiers are then arrayed around such a crystal, which register every scintillation and determine the energy of the initiating gamma quantum. These detectors can be shielded on all sides but one, to make them directional. An entire battery of such scintillation counters may be employed.

In the MeV region, other kinds of detectors are required. Above 20 MeV, the characteristic effect of gamma radiation is exploited: Electron-positron pairs are generated by the gamma quanta in an appropriate detector material, in which the electrons and positrons leave tracks as they fly off. The energy and direction of the gamma quanta can then be determined. The spatial resolution of any of these detectors, usually on the order of 1 degree of arc, still leaves much to be desired.

The first satellite of substantial size equipped for observing gamma radiation was NASA's SAS-2, launched in 1972. It was designed to scan the entire sky above 30 MeV. After 7 months, when half of the mission had been accomplished, the satellite's energy supply quit. The European satellite



NASA

The sky as it appears in gamma rays of the wavelength emitted by radioactive aluminum-26. The image is marked off in galactic coordinates; that is, the equator indicates the plane of our galaxy, the Milky Way. Most of the radiation comes from supernova remnants within the Milky Way.

COS-B went into orbit in 1975. Over a period of 7 years, COS-B succeeded in accomplishing a complete scan of the Milky Way at 100 MeV, with a spatial resolution of 4.5 degrees.

A new phase of gamma astronomy began with NASA's 17-ton Compton Gamma-Ray Observatory (CGRO), put into orbit by the Space Shuttle in April 1991. The CGRO is a kind of heavy-weight brother of the Hubble Space Telescope with responsibility for the shortwave end of the electromagnetic spectrum. The X-ray and gamma eyes of the CGRO are receptive from 50 keV to 30 GeV, a wavelength range of nearly 10^6. In its first 18 months, the CGRO accomplished a complete scan of the gamma sky with a sensitivity surpassing all previous gamma satellites by at least a factor of 10.

That provided good reason to hope that the puzzling phenomenon of gamma-ray bursts could finally be explained. Identical sodium-iodide scintillation counters, designed for observing short-duration gamma emissions, are mounted on eight sides of the platform. These instruments, called the Burst and Transient Source Experiment (BATSE), form an octahedral All-Sky Monitor, which has the entire sky in view at all times. When a burst occurs anywhere in the sky, the differing impact parameters registered at the eight modules make possible a calculation of its direction to within a few degrees. Simultaneously, an electronic signal alerts the other CGRO instruments to interrupt their routine tasks and participate in the investigation.

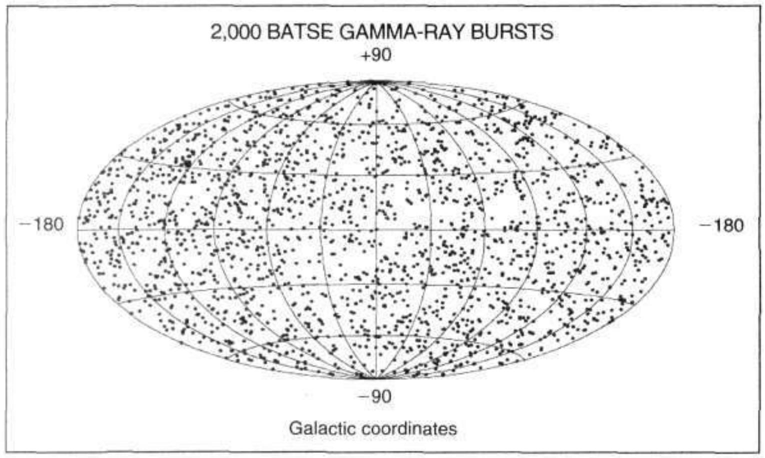
At the end of the 1980s, the overwhelming majority of astronomers still thought that gamma-ray bursts were an intra-galactic affair. The only reason for this—but also a weighty one—was that the phenomenon would otherwise entail an energy-flux density so great as to be unexplainable. But with each new burst registered by the CGRO All-Sky Monitor, one per day on average, it became clearer: There is no correlation of the phenomenon with the plane of the solar system, none with the direction of the galactic center, none with the plane of the Milky Way, and none with the positions of our neighbor galaxies in the local supercluster. The local theory of gamma-ray bursts began to teeter, but it did not fall.

BeppoSAX Makes History

To understand any celestial phenomenon, it is crucial to study it at all possible wavelengths. What might be the optical or radio manifestations accompanying gamma-ray bursts? It was not possible to determine the direction of any of the bursts registered by CGRO with sufficient precision to permit their study with the variety of special telescopes for longer wavelengths, from the Hubble to the Very Long Baseline Array (VLBA) radio-telescope. But as long as a gamma satellite can mark only a relatively large area of the sky of several degrees square, optical telescopes confront an impossible task, *comparable to pointing with one's finger at a single grain of* sand on the beach from a distance of 10 meters.

BeppoSAX, the X-ray satellite with a gamma-ray detector on board, provided the first opportunity to bring optical observations to bear on gamma-ray burst research. This satellite, developed by the Italian space agency ASI, with participation of the Dutch agency NIVR, was launched in April 1996 with one of NASA's Atlas-Centaur rockets. Germany's Max Planck Institute for Extraterrestrial Physics provided important help in calibrating and testing the X-ray optics and detectors.

The various instruments mounted on BeppoSAX are concentrated in the X-ray wavelength range. All of its specialized X-ray instruments always look in the same direction, since the purpose is to investigate single X-ray objects, such as the Crab nebula. Fortunately, BeppoSAX is also equipped with additional instruments that "keep their eyes open" beyond the immediately ongoing investigation. There are, for example, two identical X-ray wide-angle cameras that look in opposite directions, at right angles to the momentary direction of the primary instruments. If these primary instruments can be said to define the "pole," then the two wide-angle cameras are always looking at two opposite regions of the "equator" at any given time. Their field of view has a radius of 20 degrees, and their spatial resolution is 5 arc-minutes. If the wide-field cameras detect some new phenomenon, the primary mission can be interrupted, and the primary instruments can be redirected to the object in question within 12 hours or less. In addition, BeppoSAX is equipped with a monitor for gamma-ray bursts with a time resolution of one millisecond. In contrast to the All-Sky Monitor of the CGRO, this monitor's field of view is not the entire heavens, but only a band along its "equator."



The first 2,000 gamma-ray bursts registered by the Compton Gamma-Ray Observatory show their distribution on the sky. No concentration along the plane of the Milky Way is identifiable

On Feb. 28, 1997, things began to happen. The BeppoSAX gamma-ray monitor registered an 80-second eruption in a segment of the satellite's "equator," which happened to lie within the field of view of the two wide-field cameras. That was the first time the position of a gamma-ray burst was determined within a few arc-minutes. The BeppoSAX control station in Rome interrupted the primary mission and managed, within just 8 hours, to redirect the highly sensitive primary instruments toward the burst. The instruments discovered a rapidly attenuating source of X-rays, making it possible to determine the position within 1 arc-minute. That was the breakthrough. Astronomers at large telescopes around the world were informed of the success.

Some 21 hours after the burst, a Dutch-American team directed the 4.2-meter William Herschel Telescope (La Palma, Canary Islands) between the stars Aldebaran and Bellatrix in Orion. For such a telescope, there are an immense number of objects in a region of only a single arc-minute. Thus, an image of the region was prepared, and the procedure repeated 8 days later. There was in fact a "star" on the earlier image, which had completely disappeared 8 days later. This must have been the optical counterpart of the burst. But its position was now determined with a precision of 1 arc-second.

On March 13, 1997, the 3.5-meter New Technology Telescope (NTT) of the European Southern Observatory (La Silla, Chile) discovered a diffuse spot in the immediate neighborhood of this position, which was most likely a very distant galaxy.

On March 26, the Hubble Space Telescope went into action. Hubble not only succeeded in recognizing the diffuse spot as a longitudinally extended structure, but also managed to find the "star" precisely at the position determined by the William Herschel Telescope, which could no longer be seen by Earth-bound telescopes. It was too faint to obtain a spectrum. On Sept. 5, 1997, when the Hubble looked again, the object had lost brilliance by a factor of 500 since the beginning of March. The neighboring longitudinal structure, however, had not changed at all.

Gamma-ray astronomers had even better success with the 15-second burst registered by BeppoSAX on May 8, 1997. Thirty hours after detection, the 10-meter Keck Telescope in Hawaii discovered an optically changing object in the region identified by BeppoSAX, this time without having to wait for an image 8 days later. There was a surprising and sudden increase in brightness in the optical part of the spectrum. The object was, in fact, bright enough to be able to obtain an optical spectrum. U.S. astronomers recognized individual spectral lines, and, by that means, were able to measure the redshift of either the source of the burst or some object positioned between the source and us.

The spectral lines have wavelengths 83.5 percent longer than the pattern of spectral lines in a laboratory on Earth. This shift of the lines toward the red (long-wave) end of the visible spectrum, in the case of galaxies, is usually taken as an approximate measure of their distance (but not always—see box on page 54). The cited redshift would mean a distance of several billion light-years. By itself, the optical afterglow of the gamma-ray burst would then have to have an intensity surpassing the brightest supernova explosions, to be seen in our solar system with such brightness. This has given rise to the expression "hypernova," without, however, shedding any light on the process involved.

This time, however, the Hubble was unable to detect neighboring presumed galaxies. The Very Large Array radiotelescope registered a peculiar change of brightness in radio emission, a kind of flickering, which could not be associated with the object with any certainty. BeppoSAX has been able to provide positional data for a number of additional bursts.

What Is Behind the Gamma-Ray Bursts?

Attempts to explain the production of gamma-ray bursts confront the problem of having to assume a mechanism that releases extreme quantities of gamma radiation within a diameter of only a few kilometers and in an extremely short period of time. Astrophysicists have two standard answers for such questions: neutron stars or "black holes." Both are thought to be the end-phase of a massive star, which is reached after an apocalyptic catastrophe, a supernova explosion. The idea is that a neutron star still has a mass several times the solar mass, but that it has shrunk to a radius of some 20 kilometers: All of the orbital electrons have fused with the nuclear protons to form neutrons. Its density corresponds to that of an atomic nucleus (50 million tons per cubic centimeter).

Current nuclear physics claims that a massive star, whose center is no longer capable of nuclear fusion processes for lack of fuel, collapses to form a neutron star. If the star is sufficiently massive, there is no stopping the process of collapse, and the entire thing disappears into an irreparable disruption of space-time curvature, from which there is no escape—a "black hole."

There are no astronomical observations, of course, which could prove these ideas, but the general theory of relativity provides the mathematics for calculating such a phenomenon.

At the end of the 1980s, the most favored scenarios for the emergence of gamma-ray bursts were all based on ideas of neutron star instabilities, such as these:

- Material flows from a co-orbiting star and is accelerated to nearly the speed of light before striking the surface.
- A "nuclear quake" spreads radially and produces shock waves at the surface of the neutron star, which in turn produces gamma rays.
- A magnetic instability discharges; it is comparable to the processes in the corona of the Sun, but has far stronger magnetic fields.
- Comet nuclei or asteroids strike the surface.

Because our Milky Way presumably hosts a large number of collapsed stars, one might well imagine that, on average, one of these neutron stars would suffer such a disruption on any given day, in agreement with the observed number of gamma-ray bursts. But the Milky Way is disk-shaped and looks like a closed band in Earth's skies. It ought to be expected, therefore, that gamma-ray bursts would be concentrated in this band. However, the CGRO observations since the beginning of the 1990s have demonstrated the uniform distribution of the bursts over the entire sky.

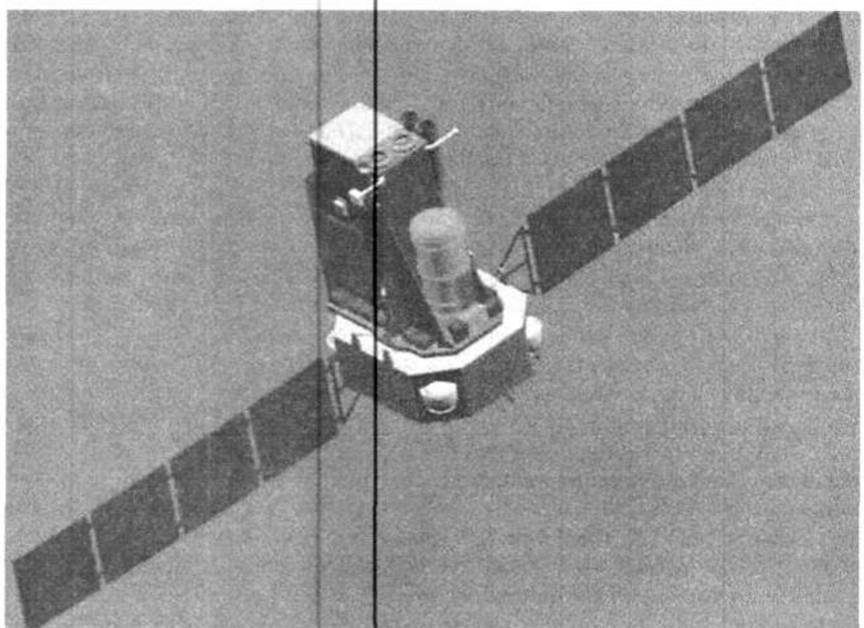
There were only two ways to salvage the model of gamma-ray bursts according to which they are produced "locally," that is, in our galaxy. On one hand, the majority of neutron stars might be located within a radius of only a few hundred light-years of the Sun. Because the galactic plane has a thickness of several thousand light-years, this arrangement might be compatible with the observed isotropy. This approach has a problem: There are surely not enough neutron stars in this region to account for a burst in the sky once each day.

On the other hand, in recent years, astrophysicists have come up with ever new evidence for the existence of an extended shell around our galaxy, in which an extremely hot and thin plasma is thought to flow. This halo has provided gamma-ray burst theorists with an important advantage: In contrast to the planar Milky Way, the halo is spherical. Might the neutron stars inhabit the halo? Since our Sun is some 30,000 light-years away from the center of the galaxy, the assumed halo neutron stars could only begin beyond a diameter of at least 200,000 light-years if the appearance of isotropic distribution were to be preserved. At such a distance, the brightness of the bursts, as observed at Earth, requires an energetic discharge in their production that compares to what the Sun generates in 1,000 years across the entire electromagnetic spectrum.

Even more difficult to explain was how so many neutron stars were able to get so far away from the galactic plane. It was assumed that each was catapulted out as a consequence of a supernova explosion of a neighboring star.

If our galaxy had such a halo, other galaxies should also have halos. So the CGRO should observe a deviation from spatial isotropy: a surplus of bursts in the directions of our neighboring galaxies—the Andromeda nebula and the Magellanic Clouds. The CGRO data show clearly that there is no such surplus.

Following the discoveries that BeppoSAX inaugurated in 1997, the only explanation left is the "cosmological" interpretation, that burst sources are located billions of light-years



ESA

The European Space Agency's gamma-ray satellite INTEGRAL is scheduled to go into orbit in 2001.

Gamma-Ray Bursts Not Local, But Not *That Far Away!*

by Halton Arp

Because gamma-ray bursts have now been identified with faint, high-redshift objects, they have been announced as extremely distant and therefore astonishingly luminous—some supposedly containing as much energy as the rest of the universe! This ignores observations showing that large, nearby galaxies eject younger protogalaxies, which, in turn, eject even younger, higher redshift objects, all in nearby volumes of space. Gamma-ray bursts should correspond to these very young, high-redshift objects. One should therefore find somewhat brighter, active galaxies fairly near gamma-ray bursts and very large, low-redshift galaxies somewhat farther away. Such galaxies are, of course, distributed all over the sky. What would happen if the astronomers actually looked around the gamma-ray bursts they have been studying so intensively? Here is just a preliminary glance at the sample so far:

- GRB 970508: There are two X-ray sources close by and a 14.4 magnitude *SBc* galaxy (UGC 03581) less than a degree away. About 1.5° away is NGC 2146, a bright, 11.2 magnitude, extremely disrupted galaxy, a radio source—of course, of very low redshift!
- GRB 970228: There are two connected spiral galaxies of magnitude 16.5 (UGC 03225) only about 1° away from this gamma-ray burst.
- GRB 971214: There are bright galaxies within about 4°: three large galaxies (NGC 3961, 4036, and 4041) and, within about 2°, a 16.5 magnitude *Sc* galaxy.

When studying high-redshift sources, the really important information is routinely discarded, when the astronomer fails to look around to see what is relatively nearby. It is not as if no one had pointed this out—it has been my message for more than 30 years.

Halton Arp, an American astronomer at the Max Planck Institute for Astrophysics near Munich, Germany, is the author of Quasars, Redshifts and Controversies *and* Seeing Red—Redshifts, Cosmology, and Academic Science.

away. In the case of the burst of May 8, 1997, if its distance is calculated from the measured redshift, we are dealing with an explosive process in which the energy released in the gamma spectrum would be 10^{45} joules, and within only a few seconds. In the models just cited, on the other hand, the calculation of the disruption of equilibrium of neutron stars yields energies in the gamma region of only 10^{31} joules.

In one year, the Sun discharges 10^{34} joules spread over the entire spectrum. The burst of May 8, 1997 thus corresponds to the energy discharge of the Sun over 100 billion years. Astrophysicists concede that our 5-billion-year-old Sun has a life expectancy of only 13 billion years.

The models for explaining gamma-ray bursts favored today still fall back on neutron stars and "black holes." These models are no longer based on the assumption of a disrupted equilibrium, but rather a complete destruction of a fused pair of neutron stars or "black holes." Alternatively, an exotic variant of supernovae—explosions of extremely heavy stars ("hypernovae")—is also under discussion, in which almost all of the energy is thought to be discharged in the gamma region, without it being possible to say precisely how that is suppose to happen. In any case, a "relativistic fireball" is supposed to occur, that is, a more or less spherical mixture of gamma radiation and particles, which explodes with a velocity of about 99.99 percent of the velocity of light.

If the fireball collides with material in its vicinity, long-wave radiation is supposed to result, which then accounts for the optical afterglow.

There are immense difficulties in reconciling this model with the details of the observed phenomenon. A calculation of such a crash of neutron stars or "black holes" on the basis of the usual physics yields energies of the order of 10^{46} joules, but not a sufficient yield in the gamma part of the spectrum. Efficiency in the production of gamma radiation above 1 percent seems to be unachievable without making artificial assumptions.

The result becomes even worse with the unavoidable pollution of the fireball with protons and neutrons. It is assumed that this "dirt" is discharged to interstellar material in the above mentioned collision, and contributes to the production of gamma radiation. But, thanks to BeppoSAX, it has been possible to demonstrate unequivocally that at least some of the gamma-ray bursts exhibit no afterglow in the longer wavelengths at all. In other words, the burst does not depend upon material in its vicinity: It can function without it.

Another problem that theorists confront has to do with the peculiar processes of the observed gamma radiation over the continuous gamma spectrum, which does not quite correspond to what the models predict.

The Next Step

If everything goes right, the European Space Agency (ESA) will put its own gamma satellite into Earth orbit in the year 2001, either with a Russian Proton rocket or an Ariane 5. The 3,600-kg INTEGRAL (International Gamma-Ray Astrophysics Laboratory), in an eccentric orbit, will circle the Earth every 2 days. INTEGRAL will cover the region of the electromagnetic spectrum from 15 keV and 10 MeV, and will thus have a far higher sensitivity than earlier gamma satellites. The specialty of INTEGRAL will be the production of spectra with higher resolution and gamma images with greater spatial resolution (12 arc-minutes). Fourteen member nations of ESA are participating, as well as the United States (NASA), Russia, and Poland.

Since the field of view of the INTEGRAL spectrometer is about 16 degrees, quite a few gamma-ray bursts will be captured over the 5 years of the expected life of the satellite. In addition to gamma-ray bursts, the scientific priorities of the INTEGRAL mission are:

• The study of the explosive nuclear fusion processes in supernovae of Type I. INTEGRAL will be able to identify them by using the spectral line of cobalt-56 up to distances of some 50 million light-years.

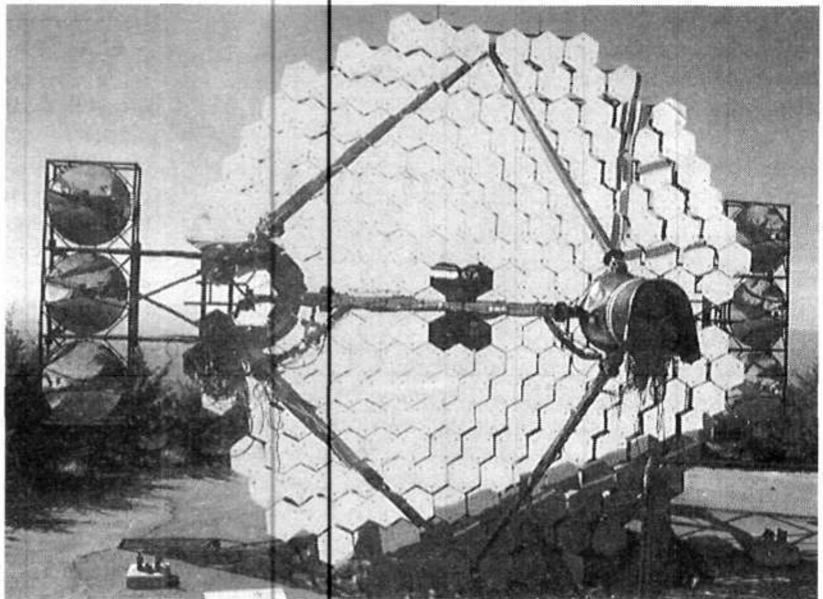
• A survey of nearly all the remnants of supernovae that have exploded in the Milky Way in the past 300 years. They are detectable in the radiation of the titanium-44 spectral line.

• Determination of locations in our galaxy at which nuclear synthesis has occurred on a large scale within the last million years. Here the aluminum-26 spectral line is exploited.

• Investigation of active galactic nuclei in a broad spectral region.

• Spectral analysis of the galactic nucleus.

• A scan of the galactic plane for variable gamma sources such as novae.



NASA

The 10-Meter Optical Reflector is the instrument of the Gamma-Ray Project of the Whipple Observatory near Tucson, Arizona. It detects Cerenkov radiation produced by gamma rays in the TeV range striking the upper atmosphere.

Another milestone in gamma astronomy is the NASA project GLAST (Gamma-Ray Large Area Space Telescope), now in the initial stages of study. The 3-ton telescope is to be sent into Earth-orbit at an altitude of 600 km with a Delta II rocket, and will scan the gamma sky with unprecedented sensitivity. The spectral region accessible to GLAST runs from 10 MeV to 300 GeV, beginning where INTEGRAL leaves off. GLAST therefore closes the gap between the softer (longer wave) segments of the gamma spectrum—those observed by CGRO and other satellites—and the extreme gamma radiation in the region of tera-electron volts, detectable until now only indirectly with Earth-bound Cerenkov counters (the Gamma-Ray Project of the Whipple Observatory). GLAST will discover some 200 to 300 gamma-ray bursts per year, and will be able to localize about half of them to within 10 arc-minutes. GLAST will obtain a high-resolution gamma spectrum for some two dozen gamma-ray bursts per year, from which the physical mechanism can be more closely studied.

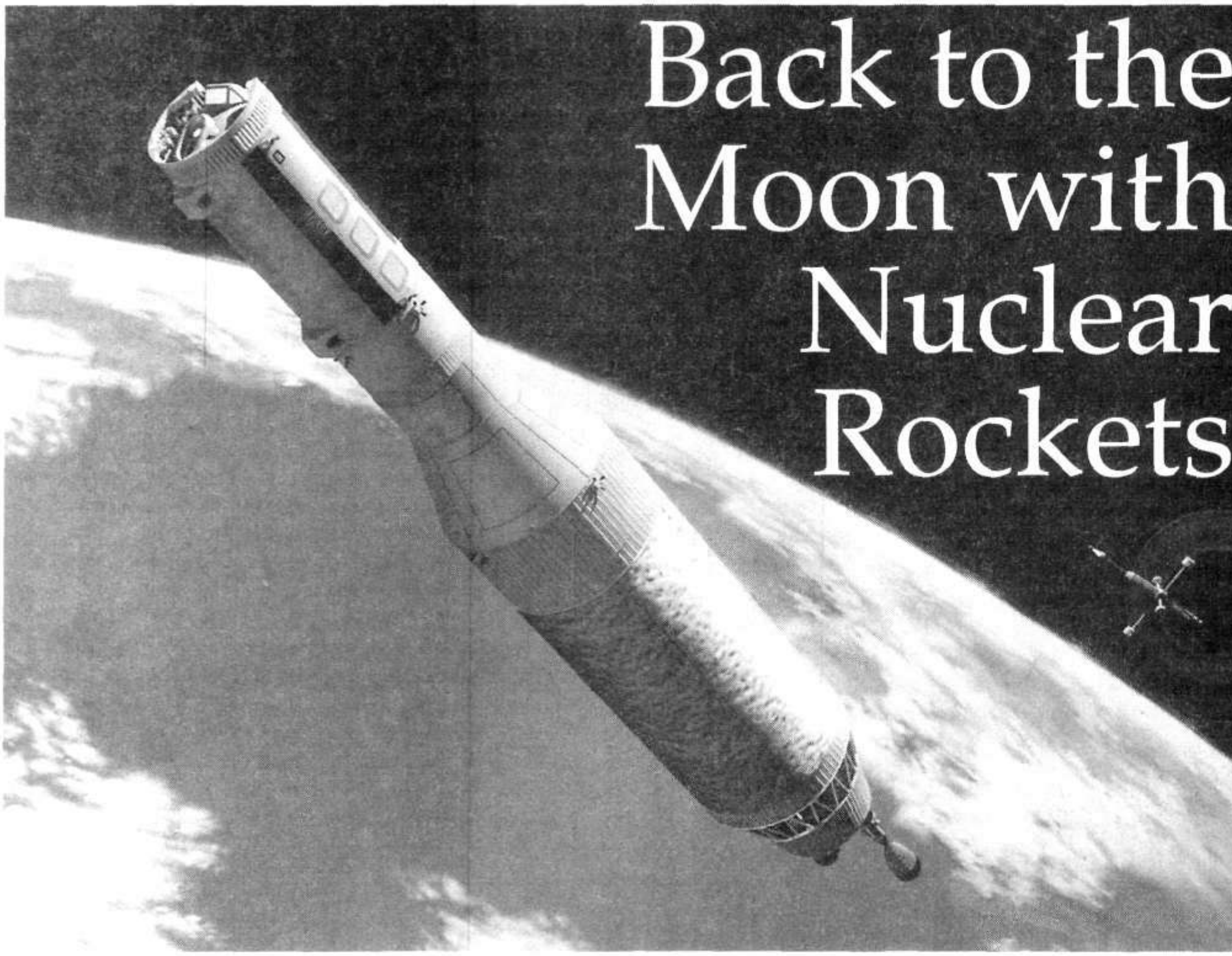
Successors to the 10-meter Whipple instrument, newly built or now under construction, are most promising. They will register shock waves in Earth's atmosphere caused by extremely-short-wavelength gamma radiation. The entire atmosphere functions here almost like a giant scintillator. A proposal for one such instrument, the MAGIC Telescope, was made by the Max Planck Institute for Physics in Munich in 1998: this instrument is to have a diameter of 17 meters and be at least 15 times more sensitive than the Whipple instrument. Although these Earth-bound stations also study numerous other phenomena of the gamma sky, they have a crucial role to play in solving the puzzle of gamma-ray bursts. If the Cerenkov counters should register an impact in the atmosphere in the TeV region, while space-based satellites simultaneously register a gamma ray burst in the same region of the sky, this it would be a severe blow against the cosmological interpretation of the phenomenon. Outer space ought to be impenetrable to gamma radiation in the TeV region, at least over distances of billions of light-years and more, because of the absorption of the intergalactic medium. That would leave the theoreticians standing there with empty hands, and the solution would require new principles of physics or astronomy.

Coda

In May 1998, newspapers all over the world published sensational, front-page headlines about a highly dramatic gamma ray burst. These results, announced by astronomers at Kitt Peak Observatory in Arizona and the Keck Telescope in Hawaii on May 6, 1998, were welcomed with headlines such as "The Biggest Explosion Since the Big Bang." This burst in the Big Dipper constellation had been detected by BeppoSAX on Dec. 14, 1997. The Arizona observatory had registered an optical afterglow only 12 hours after the burst. One hour later, astronomer Shrinivas Kulkarni and his team at the Keck Telescope also observed a faintly glowing nebula in the immediate vicinity of the burst. The spectrum of this nebula corresponds to that of a galaxy with a high rate of star formation. It manifests, however, a very high redshift ($z = 3.42$), far surpassing the redshift of the presumed galaxy of origin of the gamma ray burst of May 8, 1997 ($z = 0.835$). The distance of the galaxy was estimated at 12 billion light-years, so that the burst must have discharged 3×10^{46} joules of energy. From the standpoint of all of the models, this just goes too far. At the May 6, 1998, press conference at NASA Headquarters in Washington, D.C., Kulkarni recited all of the usual attempts at an explanation, from "black holes" to "hypernovas." Then he added, that here we have such an extreme phenomenon, that we might well be dealing with "something completely unexpected and perhaps far more exotic."

Lothar Komp is an editor of the German-language magazine Fusion, *and an economics writer for the* Executive Intelligence Review. *This article first appeared in* Fusion, *Vol. 19, No. 2, 1998, and was translated into English by George Gregory.*

Back to the Moon with Nuclear Rockets



Figures and illustrations are courtesy of Dr. Stanley Borowski/NASA

by Marsha Freeman

A Moon shuttle trip will be only a 24-hour commute—if we go nuclear.

Thirty years ago, on July 20, 1969, the first Apollo astronauts landed on the Moon, within the timeframe President John F. Kennedy had proposed eight years earlier, of a lunar landing before the end of the 1960s. To achieve this goal, the National Aeronautics and Space Administration (NASA) pushed to the limit the propulsion technology that had been under development before World War II, and created the massive Saturn V rocket, using chemical combustion as the mode of force.

Today, the International Space Station is under construction in Earth-orbit, soon to provide mankind with a multipurpose research and development facility, which can function, scientifically and physically, as a jumping-off point to more distant venues. With the International Space Station soon to be available, space planners are now considering what the space exploration programs for the 21st century should be.

There are some who have chosen to look back, rather than forward, having succumbed to the demoralization of the past 30 years since the end of the Apollo program. Mars Society founder, Dr. Robert Zubrin, for example, is convinced that there will be no return to the central planning of visionary space missions that existed in the 1960s. Asserting that the American people are "bored" with the Moon ("been there, done that"), Zubrin has proposed a series of gimmicks to entice congressional support for a "more sexy" manned Mars approach, whose main selling point is that it will be quick and cheap.

Such an approach assumes the availability and use of Apollo-era hardware; Zubrin insists that the old Saturn V rocket could be resurrected. Aside from the fact that today Saturn V rockets exist only in museums, and it is estimated that it would take 10 years and $10 billion to recreate them, even President Kennedy,

A Liquid-Oxygen Augmented Nuclear Thermal Rocket-powered transfer stage leaves Earth orbit, carrying a passenger transport module on a 24-hour trip to the Moon. In the background is the Earth-orbital International Space Station.

in 1961, did not believe that chemical propulsion systems were the future of the U.S. space program. Speaking on May 25, 1961, in his "Special Message to the Congress on Urgent National Needs," Kennedy outlined his lunar program and then requested "an additional $23 million, together with the $7 million already available, to accelerate development of the Rover nuclear rocket." The President stated:

> This gives promise of someday providing a means for even more exciting and ambitious exploration of space, perhaps beyond the Moon, perhaps to the very end of the solar system itself.

Between 1959 and 1972, the United States made what in today's dollars would be a $10 billion investment to design, develop, and test the world's first space nuclear reactors. Although very successful, the space nuclear propulsion program carried out by NASA and the Atomic Energy Commission was terminated in early 1973, when failed economic policies led to savage cuts in NASA's budget, removing lunar colonization and manned missions to Mars from the nation's space agenda.

Today, the time is near when we should go back to the Moon—but we should not go the way we did 30 years ago. We should push forward on the frontiers, creating the enabling technologies not only to travel to the Moon, but to live and work there. Only this will lay the basis for manned missions to Mars.

Why Nuclear?

The move from chemical energy to nuclear power will be a quantum leap advance in space propulsion, similar to the advances that occurred when mankind moved from foot power and unpowered water transport, to horse power, the internal combustion engine, and, finally, to jet power and electric propulsion: We will be able to go farther, go faster, and carry more cargo.

Travel in space, as anywhere else, requires large amounts of energy. Today's rockets use the energy liberated from the burning of chemical fuels to provide the thrust to move into space. But the density of the energy released from a nuclear fission, or nuclear fusion, reaction is orders of magnitude

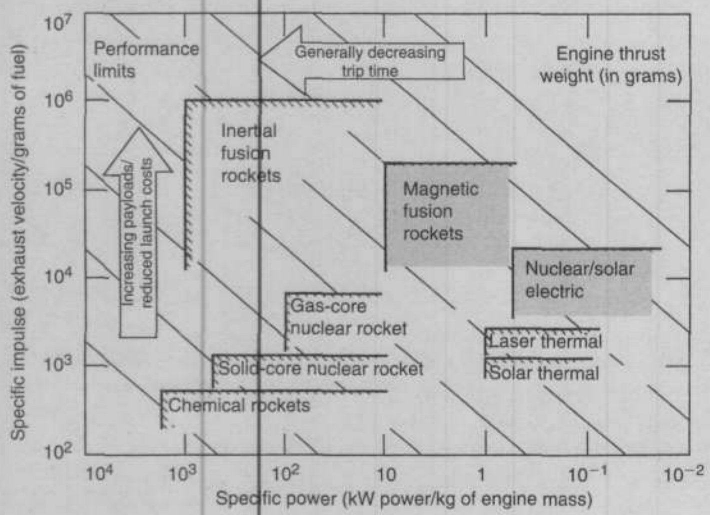


Figure 1
SPECIFIC IMPULSE AND POWER: COMPARING PERFORMANCE OF PROPULSION TECHNOLOGIES
The improved performance of the near-term solid-core nuclear thermal reactor over chemical propulsion is seen in this comparison of specific impulse and power parameters for various technologies, and the directions needed for the future.

Space Propulsion Parameters

There is more to space propulsion efficiency than simply the raw energy that is produced. One of the key performance parameters of a propulsion system is the *specific impulse,* which provides a measure of the efficiency of the thrust produced by an engine, for a given amount of propellant used, per second. Specific impulse is dependent upon the velocity of the mass produced as exhaust. The specific impulse of the Space Shuttle liquid hydrogen/liquid oxygen engines is about 450 seconds. Systems using onboard electric power, solar energy, or beamed laser power for propulsion can reach specific impulse measurements between 1,000 and 10,000 seconds.

But high specific impulse alone does not make a propulsion system. The *thrust* that is produced by any propulsion system is the product of both the propellant velocity and the mass flow rate of the exhaust. In the main engines of the Space Shuttle orbiters, a large thrust is obtained by using a large amount of propellant (high mass flow rates), which is expelled at a relatively low velocity, approximately 4,500 meters per second, through a chemical reaction.

Using nuclear fission, it is possible to obtain high thrust by expelling a relatively small amount of mass, at very high velocity, up to 10,000 meters per second.

In addition to specific impulse (the efficiency of the fuel), and thrust (the total "push" power of the system), the engine should be designed so that the *thrust-to-weight ratio* allows acceleration levels appropriate for different missions. The thrust-to-weight ratio describes the number of pounds of force per pound of engine weight.

Colonizing space necessitates families of new launch vehicles. Propulsion systems for manned spaceflight should be optimized to move people as expeditiously as possible, which requires a trade-off with the amount of freight tonnage that can be aboard. Cargo vehicles should be optimized to move as much freight as possible, and can travel more slowly.

higher. Dr. Stanley Borowski from NASA's Lewis Research Center (which was recently renamed for former Senator and astronaut John Glenn), points out that an equivalent amount of energy would be released from 13 tons of liquid hydrogen and oxygen, 2.0 grams of uranium, .5 gram of deuterium (as a fusion fuel), and .02 grams of equal parts of hydrogen and antihydrogen (See table, p. 59, and Figure 1).

In reality, the only advantage to using chemical propulsion systems today, is that we know how.

With the goal of maximizing the parameters for propulsion engine efficiency using nuclear energy, teams of scientists and engineers, both in the United States and in Russia, have been designing ingenious new systems for manned and cargo vehicles. It would be inefficient (and backwards) to plan to move mankind into space using the chemical propulsion systems of the Apollo era. We will need to take many more than three people per trip, and many tons more of supplies than those for a few-day stay.

Using nuclear energy technology in space is not an untested concept. During the space nuclear program of the 1960s, NASA designed, built, and tested 20 rocket reactors. The Rover and NERVA (Nuclear Engine for Rocket Vehicle Application) programs demonstrated the feasibility of space nuclear power, testing a wide range of engine sizes, using liquid hydrogen as both the coolant for the reactor, and the propellant, expelled to create thrust.

A few years after the start of the nuclear rocket program in the United States, a similar effort was initiated in the former Soviet Union. Although there were no integrated engine system tests conducted, nuclear and non-nuclear subsystems tests, including fuel element and reactor tests, were conducted at the Semipalatinsk facility in Kazakhstan. High-temperature fuel elements made of carbide composites were developed, capable of producing hydrogen exhaust temperatures higher than 3,000 K, or about 500 degrees more than the best NERVA fuel elements.

Ten years ago, during the celebration for the 20th anniversary of the first lunar landing, President George Bush announced that NASA should be looking toward a return to the Moon, and sending men on to Mars. NASA's Office of Exploration began investigating various technology options for reaching these goals.

A New Generation Nuclear Thermal Rocket

In 1992, NASA's Nuclear Propulsion Office at the Lewis Research Center in Ohio funded a joint program with the experts in the United States and the former-Soviet nations to design a small, advanced Nuclear Thermal Rocket (NTR) engine (Figure 2). The team included experts from Aerojet, the U.S. nuclear supplier Babcock & Wilcox, and a Commonwealth of Independent States (CIS) consortium, Energopool. In September of that year, a U.S. team visited test facilities in Kazakhstan and met with their CIS counterparts to conduct detailed studies of the CIS space nuclear reactor concept.

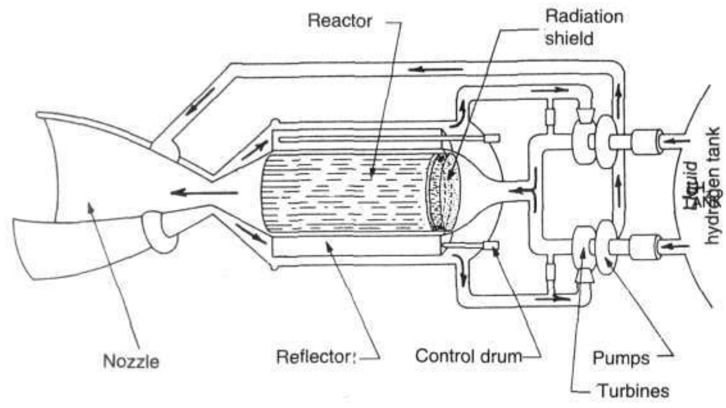


Figure 2
SCHEMATIC OF SOLID-CORE NUCLEAR THERMAL ROCKET
The heart of the solid-core nuclear thermal rocket design is shown here. Cryogenic liquid hydrogen is pumped from storage tanks (right) past the radiator to cool it. The pre-heated hydrogen is then fed through the nuclear fission reactor, heated to about 3,000 K, and expelled through the nozzle, creating the thrust for the engine.

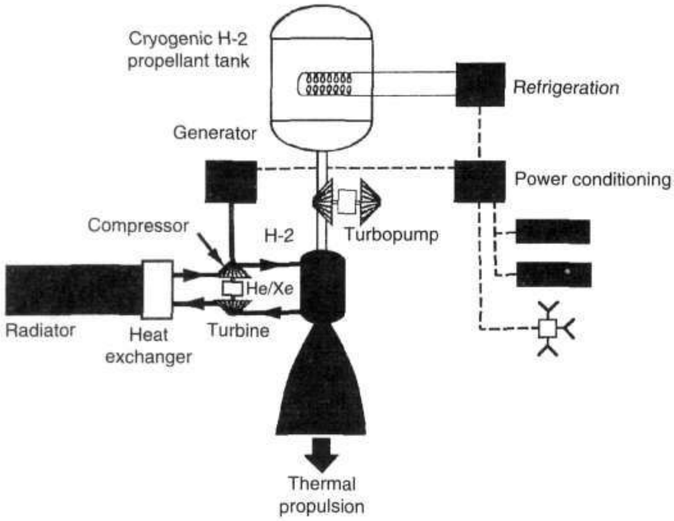


Figure 3
MOVING TO A 'BIMODAL' NUCLEAR THERMAL REACTOR STAGE
Dr. Borowski and his colleagues have proposed that the solid-core reactor used for propulsion also supply the electricity needed on board the spacecraft for life support, in the case of manned vehicles, as well as for powering the communications, electronics, and computer systems. It can also run the refrigeration system that maintains cryogenic temperatures to keep the hydrogen propellant in liquid form.

Shown here is a design for a closed Brayton cycle energy conversion system that uses the high-temperature gas from the reactor to turn a turbine and produce electric power.

This joint study came up with advanced fuel designs, such as "twisted ribbon" fuel elements, which could be adjusted according to the desired exhaust temperature. The proposed engine was designed for a specific impulse of 940 to 960 seconds, about double that of today's advanced liquid hydrogen chemical engines. Reactor tests at Semipalatinsk demonstrated hydrogen propellant exhaust temperatures of 3,100 K for more than 1 hour, and 2,000 K for 2,000 hours.

In 1993, the U.S. participants in the program suggested that a joint effort would bring significant benefits to all the countries involved. Using the existing CIS test facilities would mean that the United States would not have to spend time and resources to duplicate them. The economic situation of the Russian and other CIS scientists and engineers would be improved, and their expertise put to good use. By the end of the Bush administration, however, it was clear that neither the White House nor the Congress was willing to *pay* for any visionary manned space program, and the nuclear propulsion research was again put on a back burner.

Despite this situation, a team of experts led by Dr. Stanley Borowski from NASA Lewis Research Center, wanted to ensure that when the nation made the decision to go back to the Moon, nuclear propulsion would be seriously considered, because it is far superior to chemical propulsion or to various low-thrust options that are less attractive for manned space travel. Over the past five years, Borowski's team has greatly extended the capabilities of the CIS Nuclear Thermal Rocket design.

Every spacecraft in operation today, whether manned or not, requires an on-board electricity supply to power the electronics, computers, and scientific instruments for the mission. In the case of the Space Shuttle, chemical fuel cells provide this energy, which is required not only for spacecraft operations but also for life support. Spacecraft with longer mission times in Earth orbit, such as the Russian Mir space station, the International Space Station, commercial communications and other satellites, and near-Earth scientific satellites carry large solar arrays that convert solar energy into electricity.

Outer Solar System robotic space probes, such as the Galileo spacecraft which is orbiting Jupiter, or the Cassini spacecraft on its way to Saturn, carry a few pounds of radioactive isotopes which produce heat as they decay, and this energy can be converted to very small amounts of electricity, adequate to power the instruments on board. But if nuclear energy is used as the propulsion system of tomorrow's lunar vehicles, a ready supply of electricity for use on board can be produced from the same reactor that is powering the engines.

Borowski suggests that the nuclear-powered submarine, in which the reactor heat produces high-pressure steam to drive turbines for the ships propeller and turbines that produce all of the ship's electricity, is a good model for extending the duty of the nuclear reactor on a

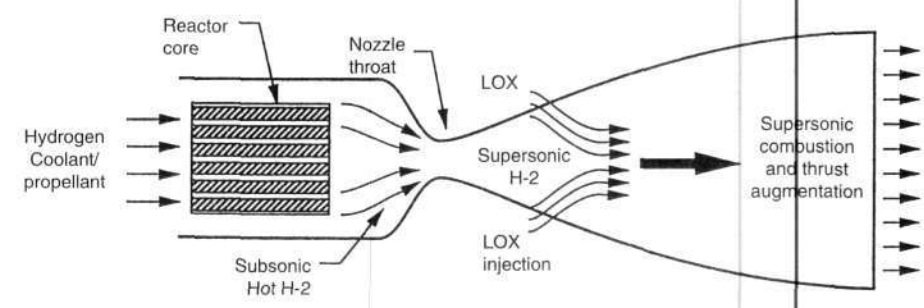


Figure 4
AUGMENTING THE NUCLEAR ENGINE WITH OXYGEN

The Borowski team has also developed a "trimodal" design for the nuclear thermal rocket, which introduces liquid oxygen (LOX) into the flow stream of the supersonic hydrogen exiting the nozzle, to increase the thrust and flexibility of the engine. The hydrogen and oxygen combust spontaneously.

THE TRADE-OFF BETWEEN THRUST AND SPECIFIC IMPULSE

	Specific impulse (seconds)				
Life (hours) Temperature (K)	5 2,900	10 2,800	35 2,600	Tankage fraction (%)	Thrust/weight ratio
Oxygen/ hydrogen ratio					
0.0	941	925	891	14.0	3.0
1.0	772	762	741	7.4	4.8
3.0	647	642	631	4.1	8.2
5.0	576	573	566	3.0	11.0
7.0	514	512	508	2.5	13.1

In the liquid-oxygen-augmented nuclear thermal rocket design, an increasing amount of oxygen added to the lighter hydrogen exhaust stream will increase the thrust of the engine, by increasing the mass of the exhaust. At the same time, however, it reduces the specific impulse of the system, by slowing down the exhaust.

The table demonstrates that while the specific impulse decreases by about 45 percent, from about 940 to 515 seconds, if the ratio of oxygen/hydrogen is 7.0, the engine thrust-to-weight ratio increases by nearly 440 percent. This increased thrust through oxygen augmentation, Dr. Borowski states, means that "big engine" performance can be obtained with small nuclear engines.

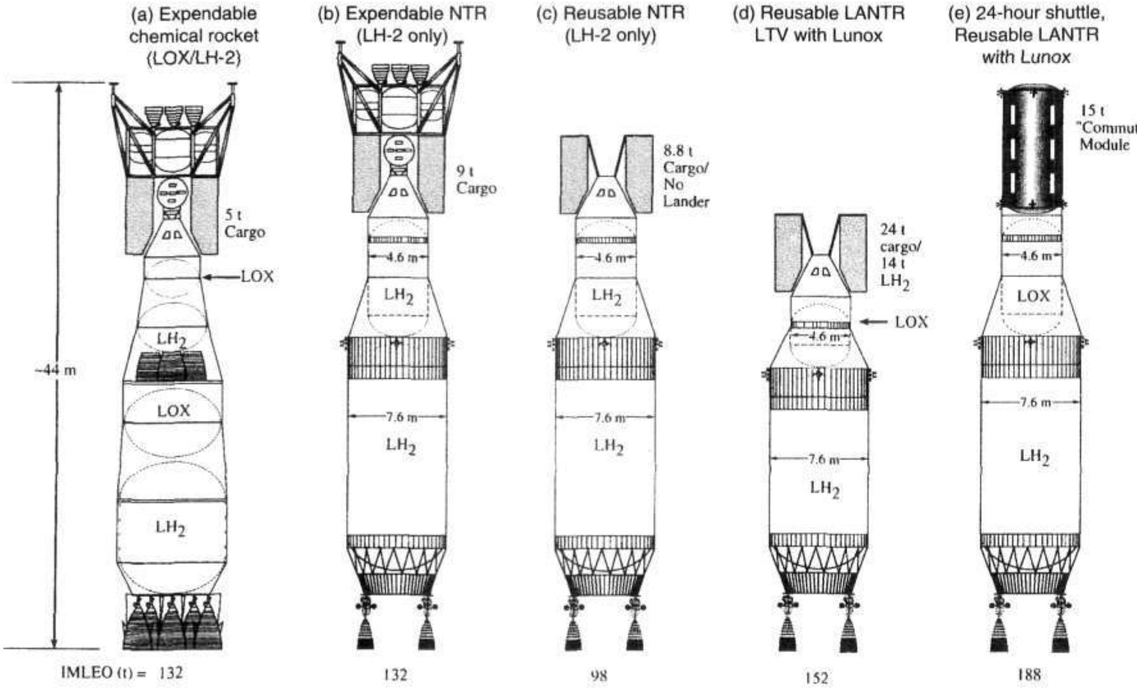


Figure 5
RELATIVE SIZE AND MASS FOR CHEMICAL AND NUCLEAR VEHICLES

An Apollo-style chemical rocket, able to land five tons of cargo on the surface of the Moon is shown in (a). Vehicle (b), with the same 132 tons of initial mass in low-Earth-orbit, substitutes a Nuclear Thermal Rocket (NTR), also expendable, for the chemical combustion, increasing payload to the surface by 80 percent, to 9 tons.

If the NTR is reusable, and lunar oxygen is available, as in (c), there is no need for a lander to be transported on each mission from Earth, because it will be refueled on the lunar surface and make round trips between the surface and lunar orbit. Nearly 9 tons of cargo could be delivered with this design.

If liquid oxygen is added to the propulsion system, in the LANTR design (d), then 24 tons of cargo can be carried to the Moon, in addition to 14 tons of terrestrial hydrogen, needed for the chemical propulsion systems of the lunar vehicles. If hydrogen were to be extracted from the ice at the lunar poles, more cargo could be carried instead.

Rockets (a)-(d) are all 84-hour vehicles. Shown in (e) is a 24-hour lunar shuttle design, where the LANTR propulsion system and lunar oxygen are in use. Payload capability is 15 tons, with increased thrust used to decrease the trip time, making possible one-day trips to the Moon.

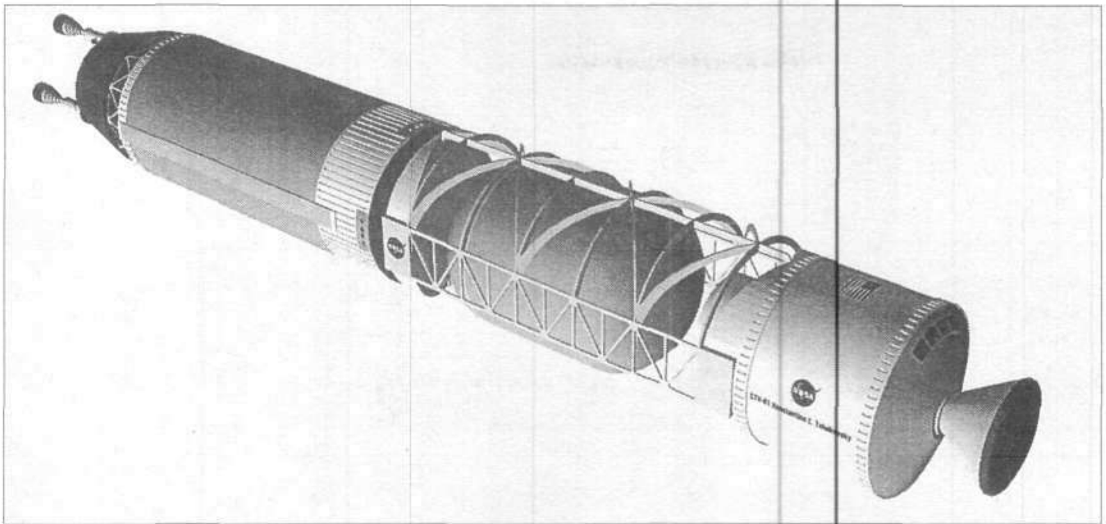
spacecraft. Bimodal operation of a solid core Nuclear Thermal Rocket is possible, producing both propulsive force and electricity, because the rocket contains substantially more fuel in its core than it consumes in its propulsion mode (Figure 3). The engine can be reconfigured, according to Borowski, so that substantial electrical power can be generated for the on-board spacecraft systems, including the active refrigeration of liquid hydrogen propellant, life support, and high data rate communications with Earth, obviating the need for a separate electric-generating system.

Quadrupling Payload with Lunar Oxygen

While examining ways to increase the efficiency of nuclear propulsion, and take advantage of an array of techniques that might be combined, Borowski and his colleagues developed the innovative "trimodal" Nuclear Thermal Rocket concept. In addition to providing the energy for the primary propulsion system, and on-board electrical power for the spacecraft, they propose augmenting engine thrust using a supersonic oxygen afterburner nozzle.

In this configuration, liquid oxygen would be injected into the bell-shaped section of the engine, where the hydrogen propellant has been accelerated to supersonic speeds. After injection, the low-mass, high-velocity hydrogen and the higher-mass oxygen would burn spontaneously, adding both mass and chemical energy to the rocket exhaust to increase thrust. The substitution of high-density liquid oxygen in place of lower-density liquid hydrogen increases the mass flow, and also reduces the mass and tank volume required for the propellant, leading to smaller space vehicles. Borowski describes this as "scramjet propulsion in reverse." In a scramjet, the engine takes in air for combustion from the atmosphere when the aircraft is flying at supersonic speeds.

In addition to increasing thrust and reducing vehicle size, the Liquid-Oxygen Augmented Nuclear Thermal Rocket (LANTR) introduces additional flexibility to the operation of



Three-dimensional view of the Bimodal Nuclear Thermal Rocket, with the Earth Return Crew Vehicle attached.

the entire system (Figure 4 and table). By varying the ratio of oxygen-to-hydrogen in the engine, it can operate over a wide range of thrust and specific impulse values, without changing the operating characteristics or power output of the nuclear reactor. For example, as the mixing ratio of oxygen to hydrogen increases from 0 to 7, the engine thrust-to-weight ratio increases by about 400 percent, while the penalty in reduced specific impulse is only about 45 percent.

The higher thrust values translate into shorter burn times for the nuclear engine to impart a required velocity, which extends the lifetime of the engine itself.

The flexibility introduced by this liquid oxygen augmentation allows the same basic propulsion system to be used among a family of vehicles with a variety of mission goals. The next quantum leap would be to avoid carrying the oxygen from Earth along in the spacecraft, but, like the scramjet, to be able to find it on the fly.

The Lunar Filling Station

There is little doubt that the first lunar resource that will be exploited for operational purposes will be oxygen, which makes up nearly half the mass of the Moon. A number of different processes have been under development through government and industrial efforts for efficient extraction of lunar oxygen from the soil, or regolith,[1] generally conceived to be used as the oxidant for chemical propulsion systems. But lunar-derived oxygen can also dramatically improve the capabilities of the liquid-oxygen augmented Nuclear Thermal Rocket (LANTR) system. Any use of "local" resources on the Moon increases the payload capability of the transport system, which does not have to carry all of its consumables from Earth.

In the plan by Borowski et al., the use of nuclear propulsion technology would be evolutionary, starting with an unaugmented, expendable Nuclear Thermal Rocket system (Figure 5). This would maximize the payload delivery to the surface, while minimizing the initial mass that must be launched from the Earth's surface to orbit. Because of the doubling of specific impulse using nuclear thermal, rather than chemical propulsion technology, the amount of payload that can be delivered to the lunar surface is 80 percent larger than that of chemical systems, for the same initial mass in low-Earth-orbit. This will translate directly into the reduced amount of time necessary for establishing advanced resource development, manufacturing, and living facilities on the Moon. The increased payload capability of the nuclear transport vehicles will allow the delivery of modular lunar oxygen production facilities to the surface of the Moon.

The first use of lunar oxygen would be to fuel the lunar landing vehicles, which will make the round trip from the surface of the Moon to the lunar transportation vehicle in lunar orbit. This will reduce the amount of liquid oxygen that must be carried from Earth orbit. As lunar-derived oxygen became readily available, reusable oxygen-augmented nuclear engines would come on line, increasing the payload throughput of the entire system. Borowski and his team estimate that with a reusable nuclear lunar transport vehicle, 400 percent more payload could be delivered on each round trip mission.

Judging from the results so far from the Lunar Prospector orbital mission, there is also the possibility of exploiting the deposits of water ice at the Moon's poles, to procure the liquid hydrogen needed as a reactor coolant and exhaust propellant for the nuclear propulsion engines.

Once the liquid-oxygen augmented "reverse scramjet" system were added, the effective specific impulse of the engine can be potentially *doubled again* to 1,500 to 2,000 seconds, or three to four times the efficiency of chemical propulsion systems. In order to deliver an equivalent amount of cargo to the Moon, a chemical propulsion system would have to deliver three times as much mass to low-Earth orbit. Specific impulse parameters at this level previously had been projected only for advanced second-generation gaseous core nuclear reactor systems; however, with the LANTR, they can be obtained using the near-term solid core nuclear technology and *in situ* propellant technologies that have already been developed and demonstrated here on Earth.

The 24-Hour Trip to the Moon

The objective of the LANTR program that Borowski has designed is to "grow" an initial lunar outpost into "permanent settlements staffed by visiting scientists and engineers representing both government and private commercial ventures."

The liquid-oxygen-augmented nuclear engine can enable 24-hour "commuter" shuttle trips to the Moon, or about what it takes to fly today from the East Coast of the United States to Asia. Exposing travelers to the radiation environment of space for as little time as possible should be one criterion in evaluating any particular propulsion system.

This nuclear lunar shuttle spacecraft would start its journey in Earth-orbit, where it would fill up with liquid hydrogen and liquid oxygen at a propellant depot. The total engine burn time for the high-velocity quick transit to the Moon is just under 47 minutes. Because the engine is designed for a 34.5 hour lifetime, the liquid-oxygen-augmented nuclear engine could make about 44 round trip missions to the Moon.

The trip, as envisioned in the LANTR program, would start with a ride on the Space Shuttle or similar future vehicle, to the Earth-orbital International Space Station. There, passengers would enter their transport module, to be brought to low-Earth-orbit inside the Space Shuttle. The passenger transport module provides the "brains" for the nuclear shuttle vehicle, and life support for the 18 passengers and two crew members during their 24-hour journey.

After leaving the space station, the passenger transport module would dock with the nuclear shuttle, which would be waiting a distance away. Acceleration levels experienced by the crew and passengers during Earth departure and translunar injection would range from less than one-quarter Earth's gravity, to perhaps one-half.

After the 24-hour trip to lunar orbit, the passenger module would separate from the nuclear shuttle, and dock with a lunar landing vehicle, which would be waiting in lunar orbit. A propellant depot in lunar orbit would refuel the nuclear shuttle for its trip back to Earth orbit. The fuel depot would also provide the lunar landing vehicle with liquid hydrogen brought from Earth (assuming hydrogen from the ice on the Moon is not used), which is needed in its chemical propulsion system to deliver the passenger transport module to the lunar surface. After landing on the surface, the passenger transport module would be placed on a "flatbed" surface vehicle for transport to the lunar settlement.

Dr. Borowski has estimated that a small advanced Nuclear Thermal Rocket engine could be developed, ground tested, and readied for flight in about seven years, at a cost of about $1.5 billion. It would be the building block for a multi-engine lunar transport vehicle, later to be augmented with oxygen combustion, and eventually, to use oxygen mined on the Moon. After a tryout period, in which the relatively short-distance trips to the Moon would become routine, the Nuclear Thermal Rocket system will be ready for a much more demanding task—manned missions to Mars.

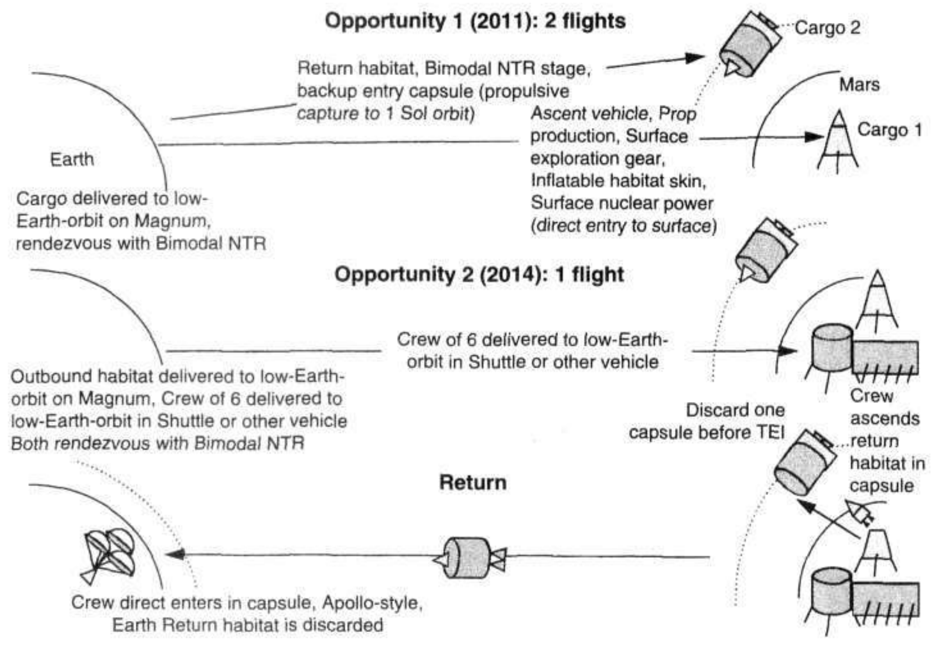


Figure 6
GOING TO MARS WITH NUCLEAR PROPULSION
NASA is studying various scenarios for manned missions to Mars in the second decade of the next century. All of the studies assume that there will be a heavy-lift "Magnum" booster available, with a payload capacity of about 80 tons, to low-Earth-orbit, and that the missions will be split between cargo flights and piloted flights. Using nuclear propulsion systems can reduce the transit time to Mars, or increase the tonnage of payload that can be transported, as compared to chemical propulsion systems.

A Family of Nuclear Vehicles for Mars

In a technical memorandum published at the end of last year,[2] Drs. Borowski and Leonard Dudzinski from NASA Lewis, and Melissa McGuire from Analex Corporation, presented a comprehensive plan for how to accomplish the goals of a Design Reference Mission to Mars that has been promulgated by NASA, using nuclear thermal rather than chemical propulsion.

One NASA Design Reference Mission considers the use of an expendable trans-Mars injection stage powered by Nuclear Thermal Rocket engines. But Borowski et al. propose that the disposal of the NTR engine after a single use is a "costly and inefficient use of this high performance stage." Instead, they propose a "family of modular 'bimodal' Nuclear Thermal Rocket vehicles," which use a common "core stage," powered by three 15,000-pound thrust engines based on the CIS design (Figure 6). These would also produce 50kW of electrical power

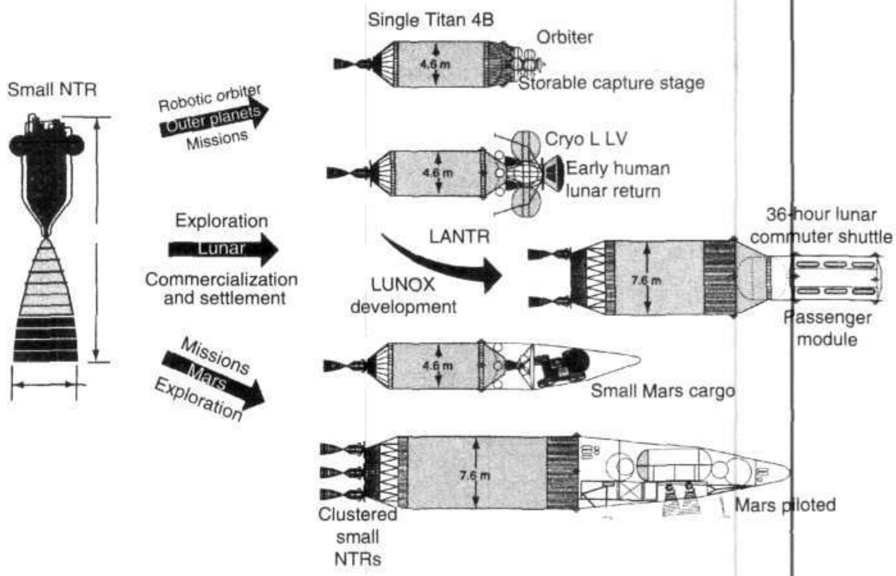


Figure 7
NUCLEAR POWER TO OPEN THE SOLAR SYSTEM
The basic small Nuclear Thermal Rocket engine will provide a versatile capability for a variety of missions. It will enable the exploration, settlement, and commercial development of the Moon, and clusters of small nuclear engines can carry men and material to Mars. In addition, unmanned robotic exploration missions to the outer planets, will benefit from the stand-alone capabilities of nuclear propulsion.

for crew life support and other requirements aboard the spaceship. Some of the advantages in this mission design are that fewer different transportation system elements are required, the initial mass in low-Earth orbit is reduced, and space operations are simplified.

Currently, NASA's Mars Exploration Study Team is assessing a variety of mission architectures and transportation options for conducting a manned mission to Mars in the timeframe of year 2014. In general outline, the proposal is centered on split cargo-piloted missions, and *in situ* production of propellant on Mars's surface. Two cargo missions would launch in November 2011, preceding the manned launch in 2014.

Borowski's team at NASA Lewis has developed an "all NTR" Mars mission option, based on using standardized engine and other components (Figure 7). Safety and flexibility are enhanced with this modular approach, vehicle design and assembly are simplified, and costs are reduced.

The first step in the manned mission is to deliver the common-core stage of the Nuclear Thermal Rocket to low-Earth-orbit on an 80-ton payload launch vehicle, dubbed "Magnum," which has been proposed by NASA for its studies. Approximately 30 days later, a second Magnum launch will deliver a structural truss, propellant tank, habitat module, and consumables to low-Earth-orbit, where rendezvous and docking with the core stage takes place. A reusable Shuttle or similar vehicle will then deliver the crew.

Because the nuclear-core stage has a higher performance capability than comparable chemical propulsion systems, it will be possible to decrease the risk of the mission to the crew, by carrying along a second, back-up Earth-return capsule. The first one would have been delivered in a preceding unmanned cargo mission. If the crew, for any reason, cannot land on Mars to retrieve the first return capsule, in this plan, they would have the spare return capsule available.

The bimodal nuclear engine, which will stay in Mars orbit after the lander takes the crew or the cargo to the surface, can produce electricity for orbital functions, including communications with Earth. It will also provide the stage that will return the crew to Earth at the completion of its stay on Mars.

The manned Mars missions that are being developed now are limited by the budgetary constraints that the space agency leadership believes will persist into the future. It is possible, with additional fuel taken to low-Earth-orbit, to trade off some of the cargo on the manned mission in order to decrease the trip time to Mars. For the health and well-being of the crew, this would be the most desirable option.

Tomorrow's Technology Today

Nuclear propulsion is next in the progression of technologies that will enhance the capabilities of mankind in space, and provide the most efficient method for colonizing the Moon. At the same time, moving from chemical to nuclear systems will lay the basis for the quantum jumps in energy technology to follow, most notably thermonuclear fusion.

When discussing the great future city that mankind will build on the Moon, space visionary Krafft Ehricke insisted that "Selenopolis will not be built with yesterday's technology." Thirty years ago, President Kennedy fully expected that the challenges of exploration to follow Apollo would also be based on tomorrow's technology, including nuclear propulsion in space. Today, tomorrow's technologies are well within our grasp.

Marsha Freeman is an associate editor of 21st Century Science & Technology *and the author of* How We Got to the Moon: The Story of the German Space Pioneers, *published by 21st Century Science Associates.*

Notes

1. See Marsha Freeman, "Krafft Ehricke's Moon: A Lush Oasis of Life," *21st Century*, Summer 1998, p. 24.
2. NASA Technical Memorandum 1998-208834. "Vehicle and Mission Design Options for the Human Exploration of Mars/Phobos Using 'Bimodal' NTR and LANTR Propulsion."

Table-Top, Ultrashort Pulse Laser Defines Frontier of Science

by Charles B. Stevens

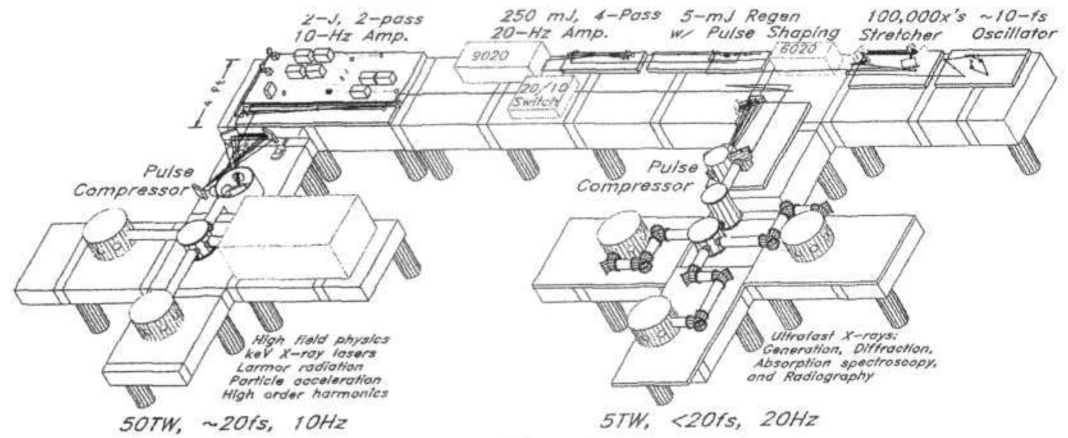


Figure 1

PETAWATT LASER TITANIUM-SAPPHIRE AMPLIFICATION CHAIN

The schematic shows the four-foot wide table system on which the petawatt laser pulse is generated, diffracted, stretched, and amplified. The energy of the pulse is increased by 100 billion.

Source: LLNL

Since its development at the University of Rochester's Laboratory for Laser Energetics in the late 1980s, the table-top, ultrashort pulse laser has proven to be a most productive workhorse on the frontiers of basic research and applied technology. From sparking the vacuum in high-energy particle accelerators, to providing an entirely new type of most efficient machine tool, the ultrashort pulse laser has continued to make major advances. Most recently, these lasers have unexpectedly demonstrated that they offer a very efficient means of generating nuclear fusion reactions in molecular clusters of deuterium gas and, in separate experiments, the generation of antimatter.

Although this new approach to fusion does not yet appear to offer a means of net fusion energy generation, the very convenient table-top laser fusion generator has major applications as a source of high-energy, fusion-generated neutrons, which can be used in various technological, scientific, and medical applications.

In addition to shedding new light on the interaction of intense laser beams with matter, these table-top fusion experiments will provide a new standpoint from which to explore the fundamental aspects of nuclear reactions themselves.

How the Petawatt Laser Works

The petawatt[1] table-top laser was first realized through the work of D. Strickland and G. Mourou, who were working at the Laboratory for Laser Energetics, the second major U.S. laser fusion laboratory, located at the University of Rochester in New York. They applied a technique that had been originally utilized in pulse amplification of radar outputs, and in compression of telecommunication transmissions: chirped-pulse amplification (CPA). In May 1996, scientists working under Michael Perry at the Lawrence Livermore National Laboratory in California, succeeded in perfecting this CPA procedure to produce the first petawatt laser pulse. This was 10 times greater than the output of the giant Livermore NOVA laser fusion system.

In producing a petawatt, ultrashort laser pulse, the first step is to generate a low-energy, broadband, ultrashort laser pulse from a solid state titanium sapphire laser. This pulse is as coherent as ordinary monochromatic laser pulses, but it consists of many different wavelengths—that is many colors—which is what makes it broadband. The pulse is then passed through a diffraction grating, which breaks it up into its various colors, as a prism does with white light. Each color of the pulse then travels on a separate path of varying length.

The pulse is reflected off a second grating, which thereby generates an elongated version of the original pulse. The "stretcher" action increases the pulse length by about a factor of 10,000. The elongated pulse is then passed through a broadband solid state series of amplifiers. In this process, the energy of the pulse is increased as much as 100 billion times.

The pulse is then passed through a second series of gratings in which the colors are recombined in space and time, regenerating the original length pulse, but at an energy level that is 100 billion times greater.

Once the petawatt laser team had achieved this new level of power density, it faced a major hurdle with respect to how to generate optical materials that could withstand the power density so that the beam could be focussed. This problem was solved by a radical new approach developed by Michael Perry and John H. Nuckolls, Livermore Associate Director at Large. (Dr. Nuckolls is the father of laser pellet fusion, who, in the 1950s, pioneered the work upon which today's inertial confinement research is based.)

Plasma Mirrors

The new approach to optical mirrors used a plasma for the mirror, which could withstand the 700 billion watts per square centimeter of the petawatt laser beam. The way this works in practice is that the first part of the petawatt laser pulse generates a short-lived dense plasma when it encounters the surface of a polished glass mirror. Just as the ionospheric plasma will reflect radiowaves of the appropriate range, the short-lived plasma has sufficient density to reflect the petawatt laser pulse. Because the petawatt laser pulse is so short, the plasma does not have time to expand during the remainder of the main body of the pulse, which is reflected.

(In addition to reflecting this higher power density, the short-lived plasma protects the remaining mirror surface and other delicate optical and diagnostic instruments down the line, which could be damaged by radiation generated when the petawatt laser pulse hits a target.)

This revolutionary breakthrough in optics indicates that critics of the Strategic Defense Initiative (SDI) back in the 1980s may have underestimated the potential for plasma "optics" in the case of the X-ray laser.

Fast-Ignition Fusion

The table-top fusion experiments in question were carried out by the Lawrence Livermore National Laboratory laser program, under a research team headed by Todd Ditmire. Livermore is also the site of the National Ignition Facility (NIF), a gigantic laser the size of a football field, which is designed to generate laser pellet fusion on a large scale. By about 2005, the NIF is scheduled to demonstrate, for the first time, that net energy can be generated by laser pellet fusion.

One application of the table-top laser technology is to provide a means of "fast-ignition," in combination with the NIF. That is, the giant NIF laser would be used to compress a fusion pellet to super-high densities, like those found at the center of stars. A table-top short-pulse petawatt laser would then provide the match to ignite fusion reactions in the center of the compressed pellet.

The fusion energy generated by this fast ignition in the center of the pellet would, in turn, provide the heat source for raising the rest of the fusion fuel in the pellet to fusion ignition temperatures. This two-step fast-ignition process could provide the means of generating overall high energy gains on the NIF. The table-top short-pulse lasers also offer entirely new methods of diagnosing what is going on during the laser fusion process and, more generally, in hydrodynamic processes.

Interactions with Molecular Clusters

In experiments that were first carried out at Imperial College in London two years ago, Ditmire and his colleagues found that powerful, short-pulse laser bursts can interact most intensely with gas jets containing molecular clusters. In particular, this intense interaction generates beams of high-energy ions. When heavy hydrogen is used to make the jet of clustered molecules, the resulting ions generate nuclear fusion of the heavy hydrogen.

It is the unique nature of this new type of interaction which makes possible the generation of high-energy beams of ions, which otherwise would have to be generated by large, high-energy particle accelerators. The interaction produces a particle accelerator on an atomic scale.

This occurs as follows: When the ultrashort pulse interacts with a large cluster—more than 1,000 atoms of heavy hydrogen—the cluster rapidly becomes ionized. The electrons thereby released are then rapidly heated by the laser pulse and, therefore, these hot electrons escape from the cluster very rapidly. This generates extremely large electric fields in the immediate region of the cluster as it is breaking up, becoming ionized. As a result, hydrogen ions produced from the breakup of the cluster are accelerated to very high energies.

In the table-top fusion experiments a pulse lasting 35×10^{-15} seconds (35 femtoseconds)[2], with an energy of 0.12 joules and a repetition rate of 10 times per second, was focussed onto a deuterium (heavy hydrogen) gas jet. This gas jet was cryogenically cooled to $-170°C$

Continued on page 75

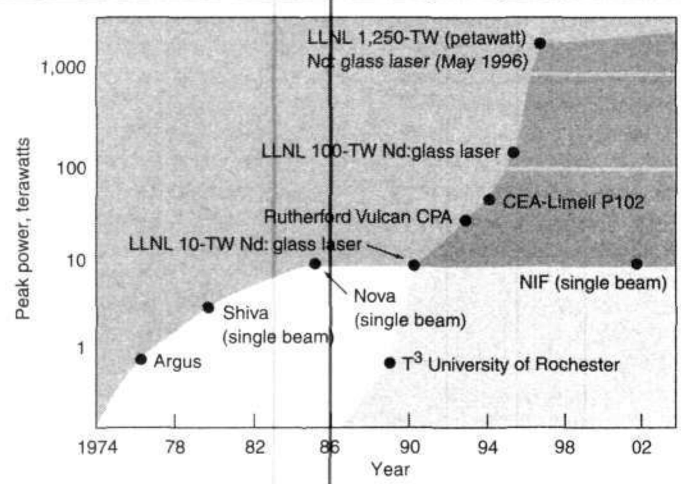


Figure 2
PROGRESS IN LASER PEAK POWER

Peak power in terawatts is given for various laser systems from 1974-2002. The figure includes the NIF single beam's expected power in 2002.

Source: LLNL

Space Probe Acceleration Anomalies Suggest Nonequivalence

by Benedetto Soldano, Ph.D.

A report recently published in the physics literature presented acceleration results of space satellites drastically at variance with both Newtonian and General Relativistic mechanics.[1] The importance of this report lies in the fact that it describes highly detailed and precise experiments, conducted over a period of approximately a decade and a half, by some of the leading experts in the field of astrophysics.

On the basis of detailed analyses of the data of a number of NASA space probes such as Pioneer 10 and 11, Ulysses, Galileo, and so on, an anomalous acceleration has been isolated that is inconsistent with both Newtonian and General Relativistic mechanics. This conclusion is based in part on an analysis of the doppler effect inherent in the transmission of information between the space probe and our terrestrial reference frame. After accounting for the effects of radiation pressure effects and planetary and interplanetary interactions, all within the framework of general relativistic dynamics, the investigators were not able to rule out the existence of an acceleration in time,

$$a_t \cong -2.8 \times 10^{-18}\ \text{sec/sec}^2,$$

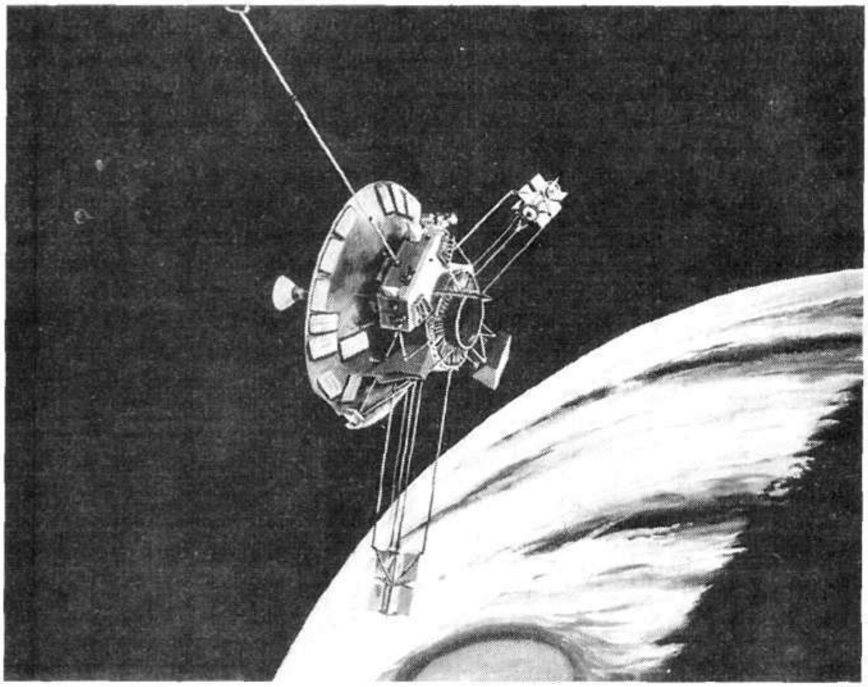
which when multiplied by the speed of light c, clearly suggests the existence of a radial acceleration

$$a_{r_e} \cong -8.4 \times 10^{-8}\ \text{cm/sec}^2$$

directed toward the Sun. An anomalous acceleration of this magnitude was isolated in all probes placed in the ecliptic plane. We shall present evidence suggesting that the anomalous radial acceleration,

$$a_{r_p} \cong -12 \pm 3 \times 10^{-8}\ \text{cm/sec}^2$$

which was found in the data of the nonecliptic probe, Ulysses, represents a real difference in magnitude from the ecliptic results obtained in Pioneer 10 and 11.



TRW

The Pioneer 10 satellite, shown here in an artist's illustration of its Jupiter fly-by.

We propose to treat these anomalous results as constituting evidence for the existence of two violations of the fundamental equality between inertial and gravitational mass[2] that sets a limit to the equivalence principle itself, a critical tenet of the theory of General Relativity. The first limit is referred to as a strong violation of equivalence, in that it applies to all four forces (electric, magnetic, gravitational, and strong). Specifically, it is based on a long range difference between inertial mass m_i and gravitational mass m_g,

$$SGF = \frac{m_{g-mi}}{mg} = -5.05 \times 10^{-12}$$

that is, in the self gravitational fraction of mass. This self binding gravitational fraction of matter is represented by a packing fraction, f_{g_i} whose value for a nucleon is as small as $f_{g_n} \cong -10^{-72}$, in contrast with $f_{g\oplus}$ for the Earth $= -4.67 \times 10^{-10}$ and $f_{g\odot}$ for the Sun $= -2.22 \times 10^{-6}$. The overall strong violation of equivalence is therefore represented by the product

$$SV_{g_i} = f_{g_i}\left(\frac{m_g - m_i}{m_g}\right);$$

as written, this quantity is positive.

The weak violation in equivalence is quantified by reference to frame dependent fluctuations in Newton's universal gravitational constant G. Relative to the Earth,

$$FF_\oplus = \left|\frac{\Delta G_\oplus}{G}\right| = 7.0 \times 10^{-11}$$

in contrast with a related solar fractional fluctuation,

$$FF_{\odot} = \left| \frac{\Delta G_{\odot}}{G} \right| = 7.18 \times 10^{-18};$$

the latter being detected by an observer on Earth as the Earth falls toward the Sun, our local planetary center of inertial and gravitational mass. The *geometric* average coupling of these two violations is

$$FF_{\text{avg}} = \sqrt{\frac{\Delta G_{\oplus}}{G}\frac{\Delta G_{\odot}}{G}} = 2.24 \times 10^{-14}.$$

The general consequences of these two violations throughout the four forces are examined in great detail in the book *Non-Equivalence: A Key to Unity* by B. A. Soldano (1997). For this article, we are restricting their application to resolving the acceleration anomalies.

In the present application of these two limits to strict equivalence, we shall focus particular attention on the initial step of the proton-proton fusion reaction in the Sun:

$$p^+ + p^+ \rightarrow n \cdot p^+ + \beta^+ + \nu_e \qquad \text{Eq. (1)}$$

which is an extremely slow weak interaction process with a 5-billion-year halflife.

The Origin of the Anomalous Radial Acceleration

The origin of the anomalous acceleration in time of the radio signal, a_t, lies in part in a detailed examination of Eq. (1). The *conversion of a proton into a neutron* establishes a connection between the strong nuclear binding charge q, where q is given by

$$\frac{q^2}{\hbar c} = 14.6$$

and the anomalous, negative magnetic moment of the neutron is given by

$$u_n = -1.91342 \frac{\hbar \bar{e}}{2m_n c}. \qquad \text{Eq. (2)}$$

Suppose this binding charge of the nucleon q undergoes a gravitational perturbation that is detectable by an observer on our terrestrial reference frame. This perturbation u'_n of the neutron's anomalous magnetic moment (Eq. 2) leads to the neutron possessing a dipole moment. The order of magnitude of this magnetic moment perturbation is fixed by the violation of the weak equivalence principle, that is, FF_{avg}:

$$u'_n = \frac{\hbar\ (q \cdot \mathrm{FF}_{\text{avg}})}{2m_n c} \qquad \text{Eq. (3)}$$

$$= 1.053 \times 10^{-26}\ \bar{e}\ \text{cm} = \mathrm{d}_n$$

This leads to:

$$\frac{u'_n}{u_n} = -5.235 \times 10^{-13} \qquad \text{Eq. (4)}$$

In analogy with the neutron's magnetic moment, u'_n is written in a magnetic moment format. However, since the fluctuation in the nucleonic binding charge ($q \cdot FF_{\text{avg}}$), shown in Eq. (3) is a consequence of two disparate non-equivalence perturbations in *G;* one relative to the Earth ($FF_{\oplus}$), and the other relative to the Sun ($FF_{\odot}$); this produces a non-local situation that could lead to an electric charge separation (d_n = 1.053 × $10^{-26}\bar{e}$ cm) which is characteristic of all electric dipole moments.

For the present, it is of interest to note that the size of this electric dipole moment, is comparable to the latest experimental upper limit for a neutron dipole moment.[3] The data from 15 reactor cycles over three years, give $d_n = -1.9 \pm 2.2 \times 10^{-26}\bar{e}$ cm. There seems to be a systematic effect in their analysis, such as a correlation of the magnetic field with reversals of the electric field, that could mimic a neutron electric dipole moment. This effect can be partially corrected using data from the external rubidium magnetometers, to give a best estimate $d_n = -3 \pm 5 \times 10^{-26}\bar{e}$ cm, or $|d_n| \leq 1.2 \times 10^{26}$ $\bar{e}$ cm at the 95 percent confidence level; a value that compares favorably with that predicted in Eq. (3). These recent results reconfirm the above upper limits.

The existence of a neutron dipole moment violates CP invariance. CPT invariance requires that ΔCP be accompanied by the violation of time reversibility. It *follows that the resultant irreversible shift* in time Δt:

$$\Delta t = \frac{u'_n}{u_n}\,(t_{\odot\text{-}\oplus}) = -2.61 \times 10^{-10}\text{sec} \qquad \text{Eq. (5)}$$

where $t_{\odot\text{-}\oplus}$, is the transmission time (498.67 secs) between the Sun and the Earth, and can be considered the key time perturbation inherent in the anomalous time acceleration measured by the NASA probes; the latter represent links between the Earth and the Sun. The negative sign of u_n in Eq. (5) constitutes the basis for the attractive nature of the anomalous acceleration in time a_t, found in the analyses of the Pioneer 10 and 11 probes. The radial nature of the acceleration is reinforced by the location of the fusion reaction in the core of the Sun, the gravitational center of all the planets in the solar system.

In obtaining an estimate of the time acceleration found in the synchronized Pioneer clocks, one must normalize the time shift represented in Eq. (5) to the square of that particular period that links both the Earth and the Sun in a gravitational resonance process involving the anomalous magnetic moment of the neutron participating in the first step of $p^+ + p^+$ fusion process in Eq. (1). In recent years, a plethora of experiments[4] have demonstrated the existence of a gravity wave frequency P, of 160.01 minutes, linking the Earth to the inner recesses of the Sun. *This periodicity presently serves as the* basis for helioseismic studies of the Sun's interior.

There is, however, a deeper connection between the neutron created in the initial step of the $p^+ + p^+$ fusion of Eq. (1) and the gravitational, g wave resonance period of 160.01 minutes. It has long been observed that there exists a neutron-hydrogen resonance[5] interaction whose magnitude of ~0.11 eVs is equivalent to a wavelength 1.7×10^{-4} cm. In the present case, the product of the anomalous magnetic moment of the neutron u_n, and the square of the period P implicit in Eq. (6) is dimensionally equal to a neutron-hydrogen "scattering" wavelength raised to the fourth power, as follows:

$$u_n P^2 + \lambda^4 = 0 \qquad \text{Eq. (5a)}$$

where

$$\lambda = 1.727 \times 10^{-4} cm \qquad \text{Eq. (5b)}$$

$$= \frac{\hbar c}{E_{n\text{-}H}}$$

Not only is the calculated wavelength in Eqs. (5a,b,c) comparable to that encountered in the aforementioned neutron-hydrogen resonance interaction but Eqs. (5a,b,c) and Eq. (6) suggest that the neutron formed in the initial step of $p^+ + p^+$ fusion in Eq. (1) could conceivably be interacting with the accompanying positron product, the anti-particle of an electron; the latter on Earth acting as the natural oscillator for the hydrogen atom that is also participating in the above resonance. Eqs. (5a,b,c) serve to confirm the proposition that it is the first step of $p^+ + p^+$ fusion in Eq. (1) that underlies the anomalous acceleration detected by space probes. That the resonance period of 160.01 minutes is gravitational in nature is suggested in the following equality of potentials:

$$300 \parallel \frac{1}{m_{\bar{e}}} \left(\frac{2\hbar}{P}\right) = \qquad \text{Eq. (5c)}$$

$$\frac{E_{n\cdot H}}{\bar{e}} \parallel = 0.1143 \text{ volts}$$

wherein $\frac{\bar{e}}{m_{\bar{e}}}$ is the ratio of the electric charge relative to its mass and $2\hbar$ is the spin of the graviton. The magnitude of the resultant voltage (0.1143 volts) represented in Eq. (5c) is comparable to the ionization potential of the first Bohr orbit of the hydrogen atom.

Calculation of the Anomalous Acceleration

In light of the intimate relationship of *the 160.01-minute period P,* to a gravitational resonance coupling between the Earth and the Sun, we shall treat our Δt in Eq. (5) as an irreversible time shift of this particular frequency. Thus the following acceleration of time a_{t_c} obtains.

$$a_{t_c} = \left(\frac{u_n'}{u_n}\right) \frac{t_{\odot\text{-}\oplus}}{P^2} \qquad \text{Eq. (6)}$$

$$= -2.83 \times 10^{-18} \text{ sec /sec}^2$$

Significantly the proposed acceleration in time given by Eq. (6) is in close agreement with that identified by the CHASMP probe, a_t. As noted by Anderson et al.,[1] *the multiplication of the time acceleration* described in Eq. (6) by the speed of light, *c*, produces a negative, radial acceleration toward the Sun, a_{r_e} (see table), a result in close agreement with *the results of Pioneer 10, where the radial* acceleration was found to be

$$-8.09 \pm .2 \times 10^{-8} \text{ cm/sec}^2;$$

and Pioneer 11 measurements, which gave

$$-8.56 \pm .5 \times 10^{-8} \text{ cm/sec}^2.$$

Non-Ecliptic Results

The preceding discussion has dealt with space probes located essentially in the ecliptic plane. On the other hand, the Ulysses spacecraft was sent into a non-ecliptic orbit that ultimately traversed both poles of the Sun as it traveled from 5.4 AU near Jupiter, in February 1992, to a perihelion of 1.3 AU in February 1995. This non-ecliptic path of the Ulysses probe enabled it to also sense any deviation from strong equivalence in the Sun. This means that one should also expect the value of the detected anomaly in acceleration to differ from the average ecliptic acceleration anomaly, which is

$$-8.5 \times 10^{-8} \text{ cm/sec}^2.$$

From a non-equivalence standpoint, the anomalous Ulysses acceleration, Eq. (7), should be precisely 3/2 times the ecliptic's acceleration anomaly obtained in Eq. (6).

$$a_{t_{pc}} = 3/2ca_{t_c} \qquad \text{Eq. (7)}$$

$$= -12.75 \times 10^{-8} \text{ cm/sec}^2$$

This larger result in Eq. (7) compares favorably with the Ulysses result

$$a_{t_p} = 12 \pm 3 \times 10^{-8} \frac{\text{cm}}{\text{sec}^2}.$$

The magnitude of the acceleration predicted in Eq. (7) reinforces our belief that the non-ecliptic anomalous acceleration isolated by Ulysses is indeed different from the value obtained by Pioneer 10 and 11.

We now turn to a justification for the precision of the commeasurable ratio (composed of whole numbers) of 3/2, used in Eq. (7).

Let us look at the magnitude of the solar violation of the strong equivalence principle:

$$SV_{g_\odot} = 1.12 \times 10^{-17}$$

and that of the solar violation of the weak equivalence principle:

$$FF_\odot = 0.71 \times 10^{-17}.$$

It is true that the ratio of the two is precisely 3/2. *as shown in Eq. 8:*

$$\frac{SV_{g_\odot}}{FF_\odot} = \frac{3}{2} \qquad \text{Eq. (8)}$$

The commensurability of the factor of 3/2 calls to mind the fact that such whole number ratios, when associated with the dynamics of planets, constitute evidence of gravitational resonance processes.[6] The fact that the ratio of the orbital period of the Sun's nearest planet (Mercury), relative to its rotational period, is precisely 3/2, has been interpreted as evidence for the existence of gravitational resonance between Mercury and the Sun. If we equate these two numerically equivalent time ratios, we have:

$$\frac{3}{2} = \frac{SV_{g_\odot}}{FF_\odot} = \frac{P_{\text{orb}}}{P_{\text{rot}}}. \qquad \text{Eq. (9)}$$

We can take the cross product of this resultant relationship (see Eq. 10) and obtain new insight into the gravitational resonance, transmission process between the Sun and Mercury. Further, Eq. (10) suggests a possible connection between the term of the solar violation of the strong equivalence principle $SV_{g_\odot}$ and the $p^+ + p^+$ fusion reaction in the Sun; in particular, the weak interaction process of positron formation accompanying $p^+ + p^+$ fusion. This gravitational connection with the solar fusion process is not surprising, when one notes that it is the Sun's collective self-gravitational compression that initiates $p^+ + p^+$ fusion by overcoming the repulsion barrier between protons.

$$SV_{g_\odot} \cdot P_{\text{orb}} = FF_\odot \cdot P_{\text{rot}} \qquad \text{Eq. (10)}$$

$$= t_{\odot\text{-}} \frac{(r_v - r_f) m_e c^2}{\bar{e}^2} \frac{G_F}{\hbar c} \left(\frac{m_e c}{\hbar}\right)^2$$

where $t_{\odot\text{-}}$ is the one-way transmission time between the Sun and Mercury;

$$CC_{\beta^+} = \frac{G_F}{\hbar c} \left(\frac{m_e c}{\hbar}\right)^2 = 3.0 \times 10^{-12},$$

is the normalized, weak interaction point coupling constant for the positron product accompanying the $p^+ + p^+$ fusion in Eq. (1). The charging ratio difference

$$\frac{(r_v - r_f) m_e c^2}{e^2} = \frac{1}{10}$$

arises from the fact that fluctuations in *G*, that is, $\Delta G_\odot$ *and SGF involve the two* classical charging radii of the positron Eq. (11a) and Eq. (11b).

$$r_f = \frac{1}{2} \frac{\bar{e}^2}{m_e c^2} \qquad \text{Eq. (11a)}$$

$$r_v = \frac{3}{5} \frac{\bar{e}^2}{m_e c^2} \qquad \text{Eq. (11b)}$$

Confirming Evidence

For many years, it has been known that there exist two different classical charging radii for the electron: one, at fixed charging radius r_f and the other, at a variable charging radius r_v. Because of the preceding gravitational fluctuation differences, both radii are required in Eq. (10).

The existence of two different charging radii for the electron, as a result of fluctuations in Newton's *G*, satisfies one of the criteria for an electron dipole moment (dimensionally of the form $\Delta e \Delta l$). The product of $(r_\nu - r_f)$ and the weak interaction normalized coupling constant for the point interaction of an electron, quantifies the Δl component of an electron dipole moment:

$$CC_{\beta^+}\,(r_\nu - r_f) = 8.45 \times 10^{-26}\text{cm}$$

The Δ charge portion of an electron dipole description is linked to an alternative description[2] of the electric fine structure constant; one based on statistical fluctuations in the charge of the electron, that is, $\Delta e = e\alpha$.

Upon combining the above two fluctuation parameters, we are led to the following prediction for an electronic dipole moment Eq. (12).

$$(\bar{e}\,\alpha)\,[CC_{\beta^+} + (r_\nu - r_f)] \qquad \text{Eq. (12)}$$

$$= 6.17 \times 10^{-28}\,\bar{e}\text{ cm}$$

Significantly, this prediction is consistent with the latest experimental upper limits.[7]

We have claimed in Eq. (3) that a weak nonequivalence fluctuation in the nucleon's binding charge q gives rise to a neutron dipole moment $d_n = 1.053 \times 10^{-26}\,\bar{e}$ cm. Moreover, these same fluctuations in Newton's universal constant G constitute a basis for a difference between the two charging radii for the electron $(r - r_f)$, as shown in Eq. (10). Supersymmetric theories indicate that a neutron dipole moment could be accompanied by the existence of an electron dipole moment—a situation precisely indicated in Eq. (12). Note that the predicted electron dipole moment in Eq. (12) is considerably smaller than $10^{-26}\,\bar{e}$ cm, the current experimental upper limits for the neutron's dipole moment.

In conclusion, we wish to briefly comment on two important questions facing physics that are directly related to the nonequivalence factors examined in the present study:

The first is that dealing with attempts to measure axions emitted by the Sun and detected on Earth.[8] If the renormalized energy-dependent coupling of an axion to two virtual photons and the electron $(a, \gamma, \gamma, \bar{e})$ has been detected and is indeed $g_{a\gamma\gamma\bar{e}} = \dfrac{2.7 \times 10^{-9}}{1\ GeV}$, then for an energy equal to the real terrestrial rest mass of a photon (2.385×10^{-17} eV), the resultant coupling is precisely equal to the product of the two nonequivalence terms examined herein, and the first diffraction constant for light (1.22). At an axion mass equal to 1.065×10^{-3} eV, only the strong nonequivalence term remains; a CP invariance violation in the strong force being the reason for the postulation of an axion.

Second, the application to the missing neutrino problem of the strong violation for the Sun, $SV_{g_\odot}$, leads to the conclusion that only 70 percent[9] of the neutrinos required to satisfy the conservation laws of

Continued on page 75

REFERENCED VALUES

Physical Constants

α	fine structure constant	1/137.0388
c	speed of light	2.9979×10^{10} cm/s
$\bar{e}$	electron charge	4.8×10^{-10} esu
$\hbar$	Planck's constant	6.5906×10^{-16} eV·s
m_n	mass of a neutron	939.55×10^6 eV/c^2
$m_{\bar{e}}$	mass of an electron	0.511×10^6 eV/c^2
$P_{☿_{orb}}$	orbital period of Mercury	87.97 days
$P_{☿_{rot}}$	rotational period of Mercury	58.6 days
$t_{\odot-\oplus}$	transmission time between Sun and Earth	498.7 sec
E_{n-h}	energy of neutron-hydrogen resonance interaction	~0.11eV
P	period of gravity resonance wave linking Earth to interior of Sun	160.01 min
G_F	Fermi coupling constant	

Nonequivalence Data

a_t	measured anomalous acceleration of signal	-2.8×10^{-18} sec/sec^2
a_{r_e}	radial acceleration in plane of ecliptic	-8.4×10^{-8} cm/sec^2
a_{r_p}	radial acceleration in polar/non-ecliptic plane	$-12 \pm 3 \times 10^{-8}$ cm/s^2
a_{t_c}	calculated acceleration of signal	-2.83×10^{-18} s/s^2
$a_{r_{pc}}$	calculated non-ecliptic acceleration	-12.75×10^{-8}cm/s^2
u_n	anomalous negative magnetic moment of neutron	$2.01 \times 10^{-14}\,\bar{e}$ cm [Eq. (2)]
u'_n	perturbation of u_n	$1.053 \times 10^{-26}\,\bar{e}$ cm [Eq. (3)]
d_n	anomalous electric dipole charge separation	$1.053 \times 10^{-26}\,\bar{e}$ cm [Eq. (3)]
Δt	time shift of transmission time	2.61×10^{-11} sec
q	nuclear binding charge	2.147×10^{-8} esu
λ	neutron-hydrogen "scattering" wavelength	1.727×10^{-4} cm
CC_{β^+}	weak interaction point coupling constant of positron in Eq. (1)	3.0×10^{-12}

Strong Violation

SGF	self-binding gravitational fraction of mass	$\dfrac{M_g - M_i}{M_g} = -5.05 \times 10^{-12}$
f_{g_n}	gravitational packing fraction of nucleon	10^{-72}
$f_{g_\odot}$	gravitational packing fraction of Sun	-2.22×10^{-6}
$f_{g_\oplus}$	gravitational packing fraction of Earth	-4.67×10^{-10}
$SV_{g_\odot}$	strong violation of equivalence (Sun)	$f_{g_\odot}$ SGF$= -1.21 \times 10^{-17}$
$SV_{g_\oplus}$	strong violation of equivalence (Earth)	$f_{g_\oplus}$ SGF$= -2.36 \times 10^{-21}$

Weak Violation

$FF_\odot$	weak violation fractional fluctuation (Sun)	$\left\lvert \dfrac{\Delta G_\odot}{G} \right\rvert = 7.18 \times 10^{-18}$
$FF_\oplus$	weak violation fractional fluctuation (Earth)	$\left\lvert \dfrac{\Delta G_\oplus}{G} \right\rvert = 7.0 \times 10^{-11}$
FF_{avg}	geometric mean of $FF_\odot + FF_\oplus$	2.24×10^{-14}

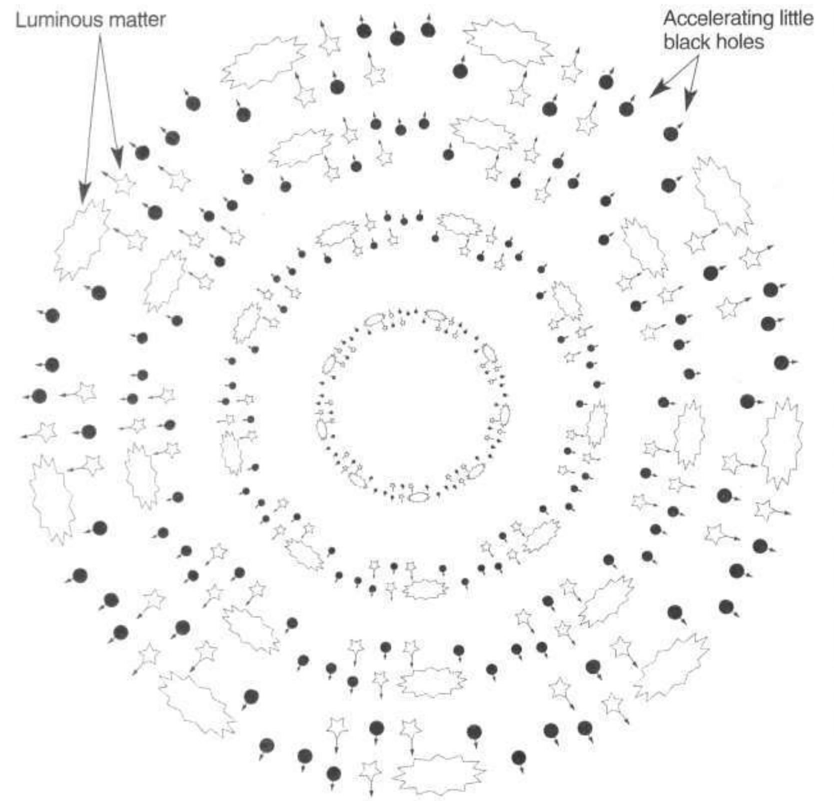
Entropy of the Universe and Little Black Hole Manifestations

by Mario Rabinowitz, Ph.D.

Based upon a general entropy argument and a tunneling model of little black hole (LBH) radiation that is contrary to Stephen Hawking's model, LBHs enter the scientific arena as excellent candidates for the dark matter of the universe and ball lightning on Earth. In addition, LBH radially beamed radiation may be the driving mechanism for one of the most remarkable and exciting discoveries of 1998: the accelerated expansion of the universe, with the implication that the universe is older, larger, and less dense than previously thought.

This discovery was totally unanticipated, and calls long-standing cosmological theories into question. It may shed light on the enigma that some stars appear to be older than the previously accepted age of the universe. One viable explanation that emerges is related to radially inward radiation from LBHs that accelerates them and the rest of the universe outward. The new discoveries radically change our concept of what drives the macrocosm, and initiate a fundamentally new quest for the laws that govern the universe on a large scale.

Since 1983, it has been known that there must be some unseen form of matter—missing mass, or dark matter—whose gravitational attraction is great enough to hold the galaxies together as they rotate. In 1983, the unheralded astronomer Vera Rubin, using spectroscopic redshift measurements on the stars in spiral galaxies, showed approximately constant linear velocities, independent of radial distance, r, rather than the expected Keplerian velocities $\propto 1/\sqrt{r}$. Their rate of rotation is so great that they would fly apart if they contained only the stars and gas we can directly perceive. Other pieces of evidence for dark matter come from clusters of galaxies, and the geometry of the universe.



ACCELERATED EXPANSION OF THE UNIVERSE

Source: Mario Rabinowitz

Since matter tends to be "clumpy" and energy is "smooth," it has been argued that on the basis of "smoothness," no more than ~65 percent of the missing mass of the universe can be matter—the remaining ~30 percent being energy. However, in terms of "smoothness," LBHs can be mistaken for energy. Because LBHs are so small, they can be "smoothed over."

Despite all the recent widespread publicity given to a possible neutrino rest mass, neither neutrinos nor any other sub-atomic particles seem to account for the missing mass (dark matter) of the universe. If these subatomic particles are prevalent, there would be discernible, widespread alteration of the reaction products of fundamental astrophysical processes, and these have not been observed. For example, it has been conjectured that WIMPS (weakly interacting massive particles, also called cosmions) collect as dark matter around massive objects like stars. If present in sufficient numbers, they should be directly detectable, but have not been, as is the case for similar candidates.

EDITOR'S NOTE

Even though he proceeds from the generally accepted mathematical physics, and we disagree with his mode of reasoning about cosmology, Dr. Rabinowitz's conclusions are unique.

Black Holes

Black Holes and the universe. Black holes were considered to be strange massive objects out of which only static (that is, non-time-varying) fields like

AMONG THE LARGEST AND SMALLEST MASSES, RADII, AND DENSITIES

To create a black hole, an object of mass M must be crushed to a density

$$\rho = \frac{M}{\frac{4\pi}{3} R_H^3} = 7.3 \times 10^{82}\, M_{gm}^{-2} \ \text{gm/cm}^3$$

where

$$R_H = 2GM/c^2 = 1.48 \times 10^{-28}\, M_{gm}\ \text{cm}$$

is the Schwarzchild radius, also often called the horizon of the black hole.

	Ordinary object			Black Hole	
Object	Mass (gm)	Radius (cm)	Density (gm/cm^3)	Radius (cm)	Density (gm/cm^3)
Universe	10^{56}	10^{28}	10^{-30}	10^{28}	10^{-30}
Galaxy	10^{45}	10^{22}	10^{-9}	10^{17}	10^{-7}
Star (Sun)	10^{33}	10^{11}	1.4	10^{5}	10^{16}
Earth	10^{28}	10^{9}	5.5	10^{0}	10^{27}
Mountain	10^{15}	10^{4}	4	10^{-13}	10^{53}
Planck Mass	10^{-5}	10^{-2}	10^{1}	10^{-33}	10^{93}
Neutron*	10^{-24}	10^{-13}	10^{14}	10^{-52}*	10^{130}*

Note

* Black holes are not supposed to form for masses less than the Planck Mass.

gravitational, electric, and magnetic fields, could get out. Everything fell in, and nothing else could come out—not even light. The first proposed mechanism for the creation of black holes from stellar evolution was by S. Chandrasekar in 1931, who argued that black holes were the final destiny of all stars with mass $\geq 1.4\ M_{sun}$. That is why all white dwarf stars have mass $<1.4\ M_{sun}$. Hawking, in 1971, was the first to propose that the high energies of the Big Bang created LBHs in the primordial universe.

There is now ample direct and indirect experimental evidence for heavy and middleweight black holes. My article in the summer 1998 issue of *21st Century Science and Technology* discussed some of this evidence for heavy black holes of millions to billions of solar masses.[1] NASA has recently released evidence for the middleweight black holes, weighing in at 100 to 10,000 solar masses. Astronomers saw hints of this new class of black holes while studying X-rays from 39 nearby galaxies. This intermediate class appears to be formed by the merging of smaller solar mass black holes. As shown in the table, LBHs have the highest possible densities.

From the table above, it also appears that our universe is a black hole, and hence, that we are probably comfortably living inside a black hole. There are no large tidal forces tearing us apart because the universe is so large. However, the numbers are just marginal for determining if the universe is indeed a black hole, so it could go either way. A simple approach can give an insight. If we equate the gravitational force to the centripetal force, we have $GmM/R^2 = mv^2/R$, where G is the universal gravitational constant, m is the mass of the orbiting body, M is the mass of the orbited body ($m \ll M$). Thus,

$$M = v^2R/G. \qquad \text{Eq. (1)}$$

From this simple key equation, much can be learned, such as an approximate value for the mass of the universe. This is how the masses of orbited bodies such as the Sun, Earth, other planets, and so on, are routinely obtained. For a circular orbit, the orbital period $t = 2\pi R/v$, and Eq. (1) becomes $t^2 = (4\pi^2/M)R^3$, which is the well-known Keplerian law that the square of a planet's period is proportional to the cube of its semimajor axis.

To show the power and generality of Eq. (1), I've made up a simple encompassing example. If we consider the universe to be Euclidean (the prevalent view), and if we use a particle (such as a photon or neutrino) moving at the speed of light, $c = v$, at the edge of the universe, then Eq. (1) gives the mass of the universe $M_u = c^2R/G$, where R is the radius of the universe. If we take the radius of the observable universe, $R = cT_u$, where T_u is the age of the universe $\sim 15 \times 10^9$ years $= 4.7 \times 10^{17}$ sec, then $M_u \sim 10^{56}$ gm. It is remarkable that this simply derived result is close to Einstein's result $M_u = (\pi/2)c^2R/G$, derived from General Relativity, when the term for the scalar curvature of the universe can be neglected. The result for a black hole is $M_u = c^2R/2G$, indicating that our universe may marginally be a black hole.

If we look a little deeper, we can notice that there is a commonality to the results for M_u that is interesting.

$$M_u \propto c^2R/G = c^3\, T_u/G \qquad \text{Eq. (2)}$$

If *c* and G remain constant, then $M_u \propto T_u$. A quantum mechanical analysis[2] gives a similar result, and an additional result: yielding both 10^{56} gm $\sim M_u \propto R \propto T_u$, and a smallest mass, 10^{-66}gm $\sim m \propto R^{-1} \propto 1/T_u$. If we take these results seriously, then they are telling us that as time increases, the mass of the visible universe increases linearly. If the universe were static (fixed), and we just see more stars with time, we would expect $M_u \propto c^3T_u^3$; that is, the mass would increase as the volume of what we see increases.

Entropy and Black Hole Radiation. The entropy of black holes is tremendously greater than the entropy of ordinary bodies of the same mass. Hence, there is a colossally higher probability that the big bang produced black holes dominantly over ordinary matter. Therefore, it appears likely that a large percentage of the mass of at least the primordial universe was composed of LBHs. As a black hole shrinks as a result of evaporative radiation, overall entropy increases. As we shall see, the beamed radiation of LBH can be a cause of the accelerated expansion of the universe. Thus, both processes contribute to the ever-increasing entropy of the universe.

Another, less compelling, but simpler argument can also be made: The time just subsequent to the big bang is a time of extremely high densities of mass-energy, which is precisely the state of little black holes. Because little black holes are made of the same primeval high density stuff, one may well expect them to be a major constituent of the remnants of the big bang. Since these are such fundamental findings, we may well ask why these conclusions were not reached some time ago. Let us see why this is so.

Hawking's black holes could not be the dark matter because they would have interfered with nucleosynthesis of protons and neutrons into deuterium , helium, and so on, that occurred in the early universe. Hawking's LBH cannot have been created in large numbers, or they would fry the universe. If LBHs radiate according to his model, Hawking concludes that they can at most make up one-millionth of the matter in the universe.

In my model, LBH are much more quiescent than Hawking's and can account for the dark matter—that is, up to 95 percent of the mass of the universe. This, in itself, is significant; however, equally notable is that my two-body interaction model for LBH radiation also makes LBHs viable candidates for *ball lightning,* and the *accelerated expansion of the universe.* Interference with nucleosynthesis is not an issue in my model of relatively quiescent beamed black hole radiation.

In 1971, Zel'dovich proposed the first model of radiation from a black hole:[3]

"The rotating body [black hole] produces spontaneous pair production [and] in the case when the body can absorb one of the particles . . . the other (anti)particle goes off to infinity and carries away energy and angular momentum."

This is quite similar to the model proposed by Hawking[4] in 1974 for radiation from non-rotating black holes. This relevant prior work by Zel'dovich was not referenced by Hawking in his original papers, although he did reference some other work by Zel'dovich, and briefly mentioned him in his 1988 popular book in a way that did not clearly credit Zel'dovich with the monumental concept of radiation from a black hole.

The effects of a second body are to lower the gravitational barrier of a black hole and to give the barrier a finite rather than infinite width, so that a particle can escape by tunneling or going over the top of the lowered barrier. By means of gravitational field emission, it is suggested here that radiation may be emitted from LBHs in a process differing from that of Hawking radiation, which has proven elusive to detect for more than 24 years. Gravitational field emission is similar to electric field emission of electrons from a metal. The lowering of the potential energy barrier by the second body can be thought of as the analogue of Schottky emission at ambient temperature.

Ball Lightning

Because LBHs can be prevalent throughout the universe, they may also be present on Earth. If so, they might manifest themselves as ball lightning, one of the few long-known and widely *accepted* natural phenomena, which are *still unexplained.* Hawking's LBHs cannot be considered as the core power source of ball lightning, because they radiate at a devastatingly high rate in all directions, which would hardly go unnoticed. Prior to the awareness that black holes can radiate, their presence in the 4-billion-year-old Earth would have been dismissed because the Earth would have been devoured after about a million years, leaving a black hole of 1 cm radius.

For my model of LBH, the downward directed radiation between the hole and the Earth can provide levitation, with a small horizontal component providing mobility. When LBHs get so small that there would be appreciable radiation, the radially inward radiation propels them away from the Earth. The downwardly directed radiation (the result of the Earth below) from a LBH acts like a rocket exhaust,[5] permitting it to levitate or fall slowly, as governed by an equation such as Eq. 5.1 (see box above).

A <1 gm little black hole has a temperature $T > \sim 10^{27}$K, so that almost all of its radiation is at extremely high frequencies with energy ~ 10^{23} eV. At a distance of many Earth-radii, the radiation is narrowly beamed toward the Earth's center. As the LBH gets close to the Earth, the radiation beam diverges to approximately the Earth's diameter, giving it a negligible power density. For example, for a beam power of ~ 10^9 W, the average power density over the surface of the Earth is ~ 10^{-9} W/cm^2. At these high energies, most of the radiation will exit the Earth. Even if it were all dissipated in the Earth, only ~ 10^{-18} W/cm^3 and ~ 10^{-19} W/gm would be absorbed.

A powerfully radiating LBH is not directly visible because the frequencies are so high. LBHs become visible indirectly as ball lightning in the surrounding air by excitation and ionization of the air molecules and atoms in interaction with a charged LBH, and by infalling particle

LBH-Accelerated Expansion of Universe

Let us look at the nonrelativistic case for velocities $v \leq 0.7$ c, where the relativistic correction is less than a factor of 2. The outward acceleration of LBH is

$$a = \frac{dv}{dt} = \frac{-c}{M}\frac{dM}{dt} - \alpha, \qquad \text{Eq. (5.1)}$$

where α is the gravitational deceleration term resulting from gravity. The LBH rate of mass decrease is:

$$\frac{dM}{dt} = \frac{-P_R}{c^2},$$

where P_R is obtained from Note 5. For a Euclidean spherically symmetric universe, and to the extent that Newtonian gravitation applies,

$$\alpha = \frac{GM}{R^2} = \frac{GMR}{R^3} = \frac{4\pi}{3}G\rho_u R, \text{ Eq. (5.2)}$$

where $\hat{u}_u$ is the average mass density of the universe inside the radius R of the spherical shell. Thus Eq. (5.1) becomes

$$a = \frac{1}{M^3}\left[\frac{\hbar c^5}{16\pi G^2}\right] \qquad \text{Eq. (5.3)}$$
$$\left\langle \exp - \left[c\,\frac{b_2 - b_1}{2\pi M}\sqrt{\frac{2M}{GR}}\right]\right\rangle - \alpha .$$

Maximizing the acceleration by $da/dM = 0$,

$$a_{max} \leq \frac{1}{M^3}\left[\frac{\hbar c^5}{16\pi G^2}\right]e^{-3} - \alpha \qquad \text{Eq. (5.4)}$$

collisions. The following 17 criteria are presented as a guide for assessing ball lightning models in general, and the LBH model in particular. LBHs meet these criteria, whereas other models generally do not.

1. *Constant size, brightness, and shape for times <~10 sec:* The large amount of gravitationally stored energy in LBHs and resulting kinetic energy accounts for the somewhat constant size, ball shape, and brightness of ball lightning. Thermally stored energy models do not have stability as a result of cooling with time.

2. *Untethered high mobility:* The lightness of the LBH (~ 1/3 gm), in which the ball lightning mass mainly resides, gives it high mobility. A small horizontal component of the exhaust force accounts for mobility in the horizontal direction. Untethered mobility vitiates against electrical discharge models of ball lightning which require attachment to good conductors (for example, metal) or poor conductors (for example, earth, wood).

3. *Generally does not rise:* The ball lightning ionized air is electrostatically bound to charge trapped in the LBH and so is forced to follow its trajectory rather than simply rise. Because heated air expands and rises, this is another criterion against thermal source ball lightning.

4. *Can enter open or closed structures:* The radius of a 1/3 gm LBH is 5×10^{-29} cm, with only a very small gravitational interaction. Thus, LBH can easily penetrate through any material.

5. *Can exist within closed conducting metal structures:* LBH have easily existed inside closed highly conducting structures such as airplanes, because of their stored energy. This criterion dictates against models that depend on external energy from electrical currents, or on electromagnetic radiation that is shielded by a conductor.

Entry into airborne craft has occurred on a number of separate occasions, and is well documented. An airplane is an excellent Faraday cage, as there are equipotential surfaces a few window diameters in. The following are excerpts from a pilot's letter to a newspaper about a report to the Strategic Air Command Weather Station of his 1960 experience:[6]

". . . USAF tanker . . . in the clouds at 18,000' A ball of yellow-white color approximately 18" in diameter emerged through the windshield . . . [at] a fast run . . . down the cabin passageway after approximately 3 seconds. . . . the Boom operator sitting in the rear of aircraft called on the interphone in an excited voice describing a ball of fire that came rolling through the aft cargo compartment abeam the wings, then danced over the right wing and rolling off into the night and clouds! No noise accompanied the arrival or departure of the phenomenon."

6. *Levitation:* The LBH downwardly directed radiation accounts for levitation. It is hard for other models to account for levitation accompanied by long horizontal motion.

7. *Low power in the visible spectrum:* The huge, directly emitted power of LBHs is in frequencies vastly higher than visible. LBHs produce ~ 10 W of optical power of ionized air. Observed intensities of light and heat are ~ 10 W, ruling out models with too much visible power.

8. *Rarity of sightings:* Because LBHs are quite rare, this explains the rarity of ball lightning sightings.

9. *Relatively larger activity near volcanoes:* LBHs may be involved in volcanic action, making ball lightning more prevalent there.

10. *Abates quietly:* Ball lightning from LBHs abates its luminosity quietly when it enters opaque materials, or comes to rest for long times, or when the charged black hole becomes neutralized.

11. *Extinguishes explosively occasionally:* Ball lightning can extinguish explosively when LBHs reach the end of their life or are disrupted.

12. *Related radioactivity:* There can be a low level of gamma rays, positrons, and other radioactive radiation associated with ball lightning. LBHs can account for radioactivity, whereas most other models cannot.

13. *Typical absence of deleterious effects:* Because of the low interaction cross section of the emitted radiation and its narrow downward beaming, the emitted power has low local power density and dissipates over a huge volume.

14. *Occasional high localized energy deposition:* The high energy content of LBHs can account for ball lightning incidents of molten materials and boiling water, when LBHs are disrupted.

15. *Larger activity associated with thunderstorms:* Thunderstorm activity may be involved in the charging of little black holes, and/or the high fields associated with thunder clouds may attract little charged black holes.

16. *Continues to glow even when stationary for short times:* An internally charged LBH can trap ~ 10 positive or negative charges externally and form a super-heavy ion-like structure. Collision of the circulating charge can ionize the surrounding air even when, as reported, the ball lightning is stationary for short times.

17. *Goes around sharp corners:* A charged LBH experiences an attractive force toward its image charge in a conductor, and either a repulsive or attractive force with a charged dielectric, depending on the relative sign of the charge. Dielectrics tend to accumulate charge in the presence of lightning clouds. Thus, charged LBHs can be guided around corners by conductors or dielectrics.

Universe Acceleration

If little black holes represent a substantial fraction (up to 95 percent) of the missing mass of the universe of mass 10^{56} gm, then (as we shall see), their radially directed inward radiation in interacting with the universe as the second body is a good candidate model for the accelerated expansion of the universe. (See Note 5.) On a solar system-size scale, the Sun's mass dominates over any kind of missing mass, because the volume of the solar system is not large enough to hold enough missing mass based on its average universal density. Thus, there is no appreciable deviation from Keplerian motion of the planetary orbits.

The box (p. 72) determines the maximum acceleration observable from the Earth in the non-relativistic case, as a result of the radiation reaction force experienced by a LBH of mass M in a spherical shell at radius R, surrounding mass m of the universe. If the total mass of a spherical shell of the universe is dominated by an ensemble of LBHs, then their acceleration will transport the rest of the bodies in the shell with them by gravitational attraction (see figure).

Discussion

Terrestrial and celestial manifestations. Many geophysical and astrophysical processes are not yet well understood. LBHs may be a link that relates to these processes, such as volcanoes, gravitational field anomalies, earthquakes, tornadoes, planetary seeding, rings of

Saturn, and copious excess heat generation in planets like Jupiter and its moons. There could be profound implications to Earth and planetary science if it could be established that little black holes are present in and on the Earth.

For example, whereas the Earth's overall density is 5.5 gm/cm^3, the Earth's lithosphere (50 miles in from the surface) has a measured density of ~ 2.7 gm/cm^3. This difference in density has been generally assumed to be the result of molten iron filling the Earth's core. LBHs in the core could help in part to account for both the increased density, as well as the total outward heat flow from the interior of the Earth, as well as the other planets. Jupiter, for example, has a very large interior production of heat. It is thought that some of its moons are heated by tidal friction in interacting with Jupiter's gravitational field, but there are significant differences in this effect for the various moons.

Hawking was the first to propose radiation from non-rotating black holes, and among the first to suggest that small black holes in stellar objects such as our Sun might help to explain the solar neutrino problem. In addition, others, such as Trofimenko, have discussed the possibility that LBHs are involved in geophysical and astrophysical phenomena, but did not consider ball lightning, nor the ramifications of LBH radiation and/or the time for LBH to devour their hosts. It is easy to see why LBH have not been considered as the core power source of ball lightning, because Hawking's LBH radiate isotropically at a devastatingly high rate.

It has not been easy to conclude that LBHs are present near the centers of astronomical bodies such as our Earth and other planets. There are two extremes with respect to this question, and they both have problems. One is the pre-Hawking radiation view, which would permit the universe to be filled with a large percentage of LBHs, but has the problem that the LBHs would gobble up any hosts they inhabit. The other is the post-Hawking radiation view, which would limit the universe to be filled with only about one-millionth of its mass with LBHs because there would be much more Hawking radiation than otherwise observed. My model permits up to 95 percent of the universe to be filled with LBHs because their radiation is relatively quiescent, and yet lets them evaporate away near the centers of astronomical bodies before these bodies are devoured.

If a slow-moving LBH falls in toward the center of an astronomical body like the Earth, it will tend to oscillate with simple harmonic motion about the center-of-mass of this body. The LBH will lose only a tiny amount of energy in its gravitational interaction with the surrounding mass. Long before it slows down sufficiently to come to rest at the center of the body, its beamed radiation will increase its amplitude of motion, eventually causing it to shoot out away from the body before ingesting it.

However, if a LBH were to come to rest at the center of a body, it would likely ingest the body over a period of perhaps millions of years before it evaporates away or shoots away. This is because, as a LBH becomes surrounded by mass, its radiation rate will first increase; but, as the mass distribution becomes uniform around it, the radiation will decrease until it eventually stops. One might be able to rekindle the radiation by producing an external asymmetry, and/or by an Aharonov/Bohm effect.

My model of LBH radiation permits more realistic speculation of how LBHs might be gathered. Harvesting LBHs might be no more difficult than mining asteroids from the asteroid belt that have LBHs in them. An entire asteroid could be towed in; or whittled down to a manageable size to carry onboard the spacecraft; or, the LBH might be shaken out of the asteroid. Another possibility might be to charge up LBHs and carefully maneuver them with an electric field.

Flawed radiation? As startling as was the theoretical discovery of radiation from black holes in 1971 by Zel'dovich, and in 1974 by Hawking, perhaps an even more startling theoretical discovery was made independently in 1975 and 1976 by Paul Davies and William Unrah. Using quantum mechanics and general relativity, they discovered what is called "acceleration radiation." The conclusion they, and the general orthodox physics community, drew from this is that the concept of a real particle is relative; that is, the existence of particles is not absolute because it depends on one's reference frame. Neither Zel'dovich-Hawking radiation, nor Unrah-Davies radiation has been observed empirically.

I have deep respect and admiration for Hawking's pioneering work and his keen insights. However, for science to progress, it is crucial to critically examine all work and find imperfections when possible. Perhaps Hawking will revise his model of black hole radiation. He has had the integrity to alter his position on at least six major topics:

1. His conclusion that a quantum cosmology/wave function of the universe proved that the arrow of time would reverse when the universe contracts.

2. Disputing Bekenstein's work on the entropy of black holes, which he later embraced.

3. After saying $T = 0$ for all black holes, then assigning $T > 0$ as a function of the mass of a black hole.

4. With respect to inflation of the universe.

5. With respect to the cosmological constant. In keeping with his long-held view, in 1998, he expressed doubts about a cosmological constant, calling the results preliminary with respect to the accelerated expansion of the universe. He said that the cosmological constant is unnecessary in light of his own views. However, in April 1999, he said: "I have now had more time to consider the observations and they look quite good. This led me to reconsider my theoretical prejudices. I now think it is very reasonable that there should be a cosmological constant."

6. The anthropic principle and multiverse cosmology. More recently, he said that the anthropic principle is fairly obvious, and he affirmed his support for it. Some cosmologists have suggested that there have been an infinity of big bangs going off in a larger "multiverse," each with different values of the fundamental constants. The anthropic principle says that only in universes where these values are compatible with life, could they be observed by beings such as ourselves.

Conclusion

In view of the lack of experimental evidence for Hawking radiation, it is meaningful and proper to examine his theory of black hole radiation with the possibility that it may be in error and/or that the formalism underlying it and accelerated radiation may need modification. Belinski, a foremost theorist in the field, unequivocally concludes, "the effect [Hawking radiation] does not exist."[7] My theory has been presented as an alternative model which can be experimentally tested. It makes experimentally verifiable connections to the missing mass of the universe, galaxy evolution, ball lightning, and the accelerated expansion of the universe.

Physicist Mario Rabinowitz is CEO of Armor Research in Redwood City, Calif. He worked at the Stanford Linear Accelerator Center for 7 years, and was a resident general scientist at the Electric Power Research Institute for 21 years, where his work included evaluation of nuclear electromagnetic pulses and cold fusion. He has more than 130 publications in scientific journals. Rabinowitz can be reached via e mail at Mario715@worldnet.att.net.

Notes

1. M. Rabinowitz, 1998. *21st Century Science & Technology* (Summer), p. 6.
   ———, 1998. *IEEE Power Engineering Review*, Vol. 18, No. 8, p. 24.
   ———, 1998. *RC Tribune*, (June), p. 9a.
2. ———, 1990. *IEEE Power Engineering Review*, Vol. 10, No. 11, p. 8.
3. Ya. B. Zel'dovich, 1971. *JETP Letters*, Vol. 14, p. 180.
4. S.W. Hawking, 1974. *Nature*, Vol. 248, p. 30.
5. M. Rabinowitz, 1999. *IEEE Power Engineering Review*, Vol. 19, No. 3, p. 65.
   ———, 1999. *Infinite Energy*, Vol. 4, No. 25, pp. 12-20.
6. M.A. Uman, 1968. *J. Atmos. & Terres. Phys.*, Vol. 80, p. 1245.
7. V.A. Belinski, 1995. *Phys. Lett.*, Vol. A209, p. 13.

Tabletop Laser

Continued from page 65

in order to form molecular clusters. The optimal laser spot size was found to be about 200 microns, which gave an estimated peak intensity of about 2×10^{16} watts per square centimeter. Measurements indicated that nearly 90 percent of the laser light is absorbed when the gas jet contains clusters. (Less than 5 percent is absorbed in case of unclustered gas jets.)

Overall, the process represents a most efficient means of transferring energy to ions. The laser photons have an energy of only a few electron volts, but through this highly nonlinear interaction, hydrogen ions with energies greater than several thousand electron volts are being generated in a very efficient manner.

Applications

The table-top laser cluster fusion system is not yet a prospective candidate for fusion energy generation, but it has immediate and potentially major technological applications. It is usually very difficult to generate large quantities of fusion neutrons, or any types of neutrons whatever. The table-top system promises to provide a compact and cheap method of neutron generation. Such a generator would be crucial for development of fusion power plants that are based on more conventional laser pellet or magnetic confinement approaches. The table-top neutron generator would be used to find and test materials for a fusion power plant.

Neutrons are also currently utilized in geological and materials testing technologies, and the table-top generator could provide a major advance in these areas. In addition, the cluster approach could provide a direct means of generating medical isotopes.

This last possibility underlines the fact that the table-top laser cluster approach could be a means of performing fundamental research into nuclear processes and reactions. That is, ion beams generated in a cluster, could interact with other clusters and with the products of previous reactions. The table-top system is open to these experimental possibilities. In exploration of this potentially new realm, entirely new prospects for nuclear energy could be derived.

Similar research on laser-cluster interactions is also being carried out at the Saclay Laboratory in France under the direction of Martin Schmidt.

Antimatter Generation

A second table-top laser with a 1 femtosecond pulse length was directed onto thin gold films. This led to the generation of antimatter electrons, called positrons. This is believed to occur as the intense plasma generated by the interaction of the petawatt laser pulse with the gold film acts like a particle accelerator, accelerating electrons to energies as high as 100 million electron volts. Some of these electrons then radiate gamma rays, which then generate pairs of electrons and positrons. As the Livermore team working on this, headed by Tom Cowan, reports: "Thus laser photons at the electron-volt level can, by teaming up, initiate the sort of million-electron-volt nuclear reactions that normally take place at an accelerator."

Notes

1. A petawatt is 10^{15} watts—1 quadrillion watts.
2. A femtosecond is one quadrillionth of a second.

Acceleration Anomalies

Continued from page 69

energy, momentum, and spin, will ever be detected. Consideration of the oscillations between m_g and m_i lead to the prediction that the remaining 30 percent fraction, which is not detectable, does not participate in any neutrino flavor, leptonic charge changes, although there exists firm evidence that neutrinos do oscillate.[10] In fact, the missing non-conservation fraction participates in a rare baryon non-conservation process leading to a massive graviton, that is, $(p^+ + p^+ + e^- + e^- \rightarrow 2\hbar)$, a graviton mass density that can be quantitatively related to the relic radiation of the universe (2.726 K).[11]

Dr. Benedetto Soldano is a member of 21st Century*'s Scientific Advisory Board.*

Notes

1. J.D. Anderson, P.A. Laing, E.L. Lau, A.S. Liu, M.M. Nieto, S.G. Turyshev, 1998. *Phys. Rev. Lett.*, Vol. 81, No. 14, pp. 2858-2861 (Oct. 5).
2. B. Soldano, 1977. *Non-Equivalence: A Key to Unity*, Oak Ridge, Tenn.: Grenridge Press.
3. P.G. Harris et al., 1999. *Phys. Rev. Lett.*, Vol. 82, No. 5, pp. 904-907 (Feb. 1).
4. A.B. Severny, A.A. Kotov, T.T. Tsap, 1976. *Nature*, Vol. 259, pp. 87-89, (Jan.).
   D.E. Thomsen, 1978. *Science News* (April 22).
   D. Gaugh, 1983. *Nature*, Vol. 304, No. 25, pp. 689-690 (Aug.).
   J.R. Brooks, G.R. Isak, H.B. Vander Raay, 1976. *Nature*, Vol. 259, pp. 92-95 (Jan. 15).
   D.B. Guenther, P. DeMarque, 1984. *Astrophysical J.*, Vol. 277, L17-L19 (Feb.).
5. Donald J. Hughes, 1959. *The Neutron Story* (New York: Doubleday Anchor Books), pp. 128-129.
6. E.P. Smith, K.C. Jacobs, 1973. *Introductory Astronomy and Astrophysics*, (London: W. B. Saunders Co., pp. 86-87).
7. S.A. Murthy, D. Krause, Z.L. Liand, L.R. Hunter, 1989. *Phys. Rev. Lett.*, p. 63, p. 965.
   K. Abdullab, et al., 1990. *Phys. Rev. Lett.*, pp. 65, 3347.
   P. Nath, 1991. *Phys. Ref. Lett.*, Vol. 26, No. 20, p. 2565.
8. F.T. Avignone, K. Zioutos, et al., 1998. *Phys. Rev. Lett.*, Vol. 81, No. 23, pp. 5068-5071 (Dec. 7).
9. John N. Bahcall, Raymond Davis, Jr., Peter Parker, Alexei Smirnov, Roger Ulrich, 1994. *Solar Neutrinos: The First Thirty Years* (New York: Addison-Wesley Publishing Company).
10. C.A. Athanassopoulos et al., 1995. *Phys. Rev. Lett.*, Vol. 75, No. 14, p. 2658.
    C. A. Athanassopoulos et al., 1986. *Phys. Rev. Lett.*, Vol. 77, No. 15, p. 3028.
    L. Borsdovsky et al., 1992. *Phys, Rev. Lett.*, Vol. 68, No. 3, p. 274.
    J.E. Hill, 1995. *Phys. Rev. Lett.*, Vol. 75, No. 14, p. 2654.
11. R.L. Davis, H.M. Hodges, G.F. Smoot, P.J. Steindart, 1992. *Phys. Rev. Lett.*, Vol. 69, No. 13, pp. 1856-1859 (Sept. 28).

Can a Dark Age Discover Edison?

by Anton Chaitkin

Edison: A Life of Invention
Paul Israel
New York: John Wiley and Sons, 1998
Hardcover, 552 pages, $30.00

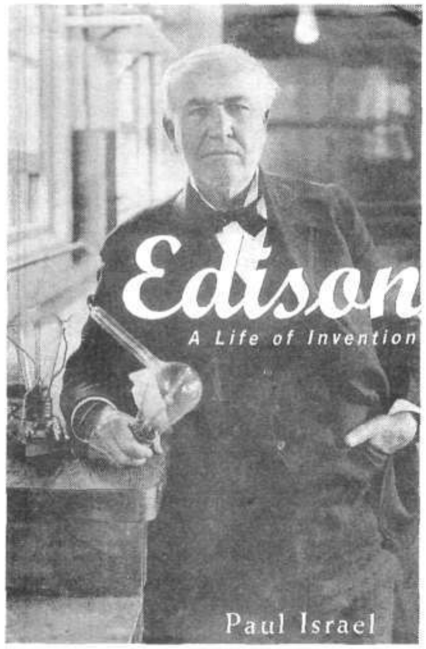
Thomas Edison began his electric light project in the summer of 1878. By 1888, hundreds of Edison's power stations were already installed, and beginning to make electricity available to the world. The story of this 10-year campaign is the most compelling section of Paul Israel's huge biography. Israel depicts the frantic energy of Edison and his devoted laboratory and workshop teams.

As managing editor of the Thomas Edison Papers at Rutgers University, the biographer brings literally millions of documents to bear on his description of Edison's inventive methods, the division of labor among Edison's assistants, and the creative environment that reached its peak in the drive for the electric light.

The biographer/archivist has great resources, and this is a rich book.

We have, for example, Edison on Shakespeare: Richard III was "said to have been his favorite character, and whenever his duties in the office permitted, he would arise from his instrument, hump his back, bow his legs and proceed with 'Now is the winter of our discontent,' to the great amusement of his fellow-operators." And, "Ah, Shakespeare! That's where you get the ideas! My, but that man did have ideas! He would have been . . . a wonderful inventor, if he had turned his mind to it. He seemed to see the inside of everything. . . ."

We have the fascinating information of Edison's father, Samuel, fleeing from an indictment for high treason in Canada, his estate being seized by the British imperial authorities, while Samuel's brother, Marcellus, was imprisoned in the same anti-British revolutionary movement of 1837-1838. Thus, the Edisons became Americans.



These gems are, however, scattered along with thousands of other facts in a chronological account of Edison's life that paints an admiring portrait—but fails to tell the necessary story.

A World-Historical Struggle

Thomas Edison and his sponsors—his political, industrial, and scientific guides—were engaged in an intense struggle with their opponents at the very center of world history. A reader might plough through Paul Israel's biography, following Edison in his home and workshop over three quarters of a century, and still be oblivious to Edison's real identity and the strategic nature of his life's work.

Elements of the story are there, strewn about the book. Four persons show up in the narrative as Edison's friends: partner and business manager Edward H. Johnson, overseas business agent George Gouraud, financial backer Josiah Reiff, and science counselor George Barker. Although the first three are each haphazardly identified as having ties to Philadelphia industrialist William J. Palmer, there is no discussion of the four as representatives of the Philadelphia-based American nationalist political-industrial leadership.

And banker J. Pierpont Morgan makes his appearance, to extend his constricting financial fingers around the enterprise. But despite including numerous quotations from Morgan and his agents showing their antagonism to Edison's philosophy, the biographer does not even suggest Morgan's international identity, nor the warfare of his British faction against the American nationalist industrialists.

Paul Israel takes no notice of the desperate fight taking place: Shall the United States and the world be rapidly developed as modern republics, or shall Old World-style aristocracy be preserved in power, by preventing such a "dangerous" increase in the living standards, education, and power of emerging populations?

Without this context, the enormous impact of Edison's accomplishments is not properly seen—the change effected, from no lights, no power, to lights on! Neither is one conscious of the change that is today still being delayed, by the throttling of America's initiative to industrialize the whole world.

Without this context, Edison's life story can have no shape, no proportionality. One continues on in a straight line right through Morgan's final theft of the main enterprise, perhaps without even noticing that the climax has been reached.

In Paul Israel's case, the problem is not bad intentions, as it was, for example with Robert Conot's 1979 piece of filth, *A Streak of Luck: The Life and Legend of Thomas Alva Edison.* Israel and his Rutgers co-workers have done a wonderful service in organizing and microfilming the vast Edison papers, a collection whose supervisors, the Greenie-tinged National Park Service, seemed not to care a heck of a lot about.

Paul Israel is sympathetic to Edison. But the recent era has been one in which one does not dream of radically increasing the power of man over nature. Our economy bows down to the hyper-speculative Dow Jones "Industrial" Average, whose star is J.P. Morgan, while the Free-Market god shuts industry everywhere. We even impose devastating sanctions against backward countries to prevent them from acquiring modern technology that could pose a "threat."

An uncritical member of such a society will have difficulty reading the true spirit and directionality of the classic United States of America, that experiment in the uplifting of mankind, of which Edison's enterprise was a great project.

It is as if a creature living in a fracture zone at ocean's bottom, were to somehow snare a colorful sea-bird. Down below it would be black, with strange side fins.

In keeping with the Zeitgeist, Israel views technology as having a certain capability for improving humanity, after which, he believes, it makes increasing mischief. So, the hypothesis on Edison becomes: He invented the modern industrial research laboratory, which then proceeded far in advance of him, under the more efficient corporate auspices. Good old Prometheus is obsolete.

The National Party Behind Edison

But we can find a powerful story lurking among Paul Israel's details. Let us first set the stage, as he does not.

After being pinned down for many years under Free Trade and slaveocratic policy, having survived the Civil War intact, the United States rushed forth to industrialize the universe. Lincoln's assassination had fastened the Free Trade racist Andrew Johnson on the White House; but the 1868 election made General Grant the President, and all stops were off.

The first transcontinental railway (Union Pacific), started during the war, opened for business in 1869. The Northern Pacific, Lincoln's second projected route West, then commenced construction. The brand new steel industry, protected by prohibitive tariffs, fired up for rails, locomotives, bridges, and farm machinery.

The nerve center for this political and industrial revolution was the nationalist faction which Benjamin Franklin had long before established in Philadelphia. The group's partners controlled the Pennsylvania Railroad, the nation's biggest company; the Jay Cooke banking house, which handled the federal government's financing and organized the Northern Pacific construction; the University of Pennsylvania and the Franklin Institute, center of a worldwide alliance of scientists devoted to man's improvement; and a vast set of railroads, coal mines, and iron and steel mills, including Andrew Carnegie's operations.

Edison National Historical Site, National Park Service

Thomas Edison: "Shakespeare would have been a wonderful inventor—he seemed to see the inside of everything."

Their long arms helped move mountains everywhere. In 1868, Japanese revolutionaries set up a modern central government inspired by students of Philadelphia economist Henry Carey, who had also been Lincoln's chief economic guide. The American nationalists assisted in building Japan's railroads and modern industry, and pushed industrialization plans with their modernizer friends in the leadership of Russia, China, Germany, and Latin America.

Immediately after the Civil War, the Philadelphians assigned one of their junior partners, William J. Palmer, to manage construction of the Kansas Pacific railroad. A dashing Civil War Medal of Honor-winning cavalry officer, Palmer set off West with his chief personal assistant Edward H. Johnson. Working in association with Palmer's colleague Josiah Reiff, they pushed the line from Kansas to Denver between 1866 and 1870; and they planned a connecting national railroad all through Mexico. Sometime in this period, Palmer's agent George Gouraud moved to England to represent the Palmer enterprises in London.

By 1871-1872, the Philadelphia partners controlled the Union Pacific. Jay Cooke was negotiating an industrial banking arrangement with Japan, the start of a projected world-spanning belt of railroads, canals, and shipping lines that could obliterate British Empire power, and assist powerful nation-building in Russia, China, and Western Europe.

Late in 1870, William Palmer's associates founded the Automatic Telegraph Company, to compete with Wall Street's Western Union. In this effort, Palmer and Reiff went into partnership with George Harrington, who had been President Lincoln's deputy Treasury secretary.

Enter Thomas Edison

At this point, Paul Israel's narrative of Edison's life intersects our wider story. Palmer initiated the Automatic company's full-time employment of the young telegraphic inventor Thomas Edison, who had already been working on contract for the Automatic as well as Western Union.

In 1872, the Palmer company's managers, Josiah Reiff and Edward Johnson, arranged to pay Edison a regular salary and a minimum of $10,000 for each patent. The Palmer associates did everything possible to establish Edison, whose genius they recognized, as an independent inventor. Palmer's agent George Gouraud soon arranged to represent Edison's interests in Britain.

Aside from identifying Johnson, Reiff, and Gouraud as associated with "railroad magnate William Palmer," biographer Israel gives us only the following information on Edison's relationship to these sponsors: "Edison's . . . support for Republican politicians had [mainly] to do with the party's role in promoting policies favorable to industrial capitalism, particularly a protective tariff."

Israel does note that Edison was an intensive reader of Thomas Paine's political writings, as was Edison's revolutionary refugee father. (He neglects to mention that Edison wrote the preface to an edition of Paine's works.)

It is at this juncture that the banking house of J.P. Morgan enters the picture, although Morgan does not directly intersect the Edison story (or Israel's narrative) until the light and power project some years later.

Morgan's Anti-nationalist Syndicate

J.P. Morgan and Company was originally established in 1871 as Drexel, Morgan and Company, located in Philadelphia and New York. It was an extension of Morgan's father's London bank, assigned by the British establishment to destroy the Philadelphia nationalists. Morgan's firm ran a smear campaign and financial warfare that in 1873 bankrupted the Jay Cooke banking house, consequently plunging the United States into depression and gravely weakening the Philadelphians. An international British-led syndicate of Morgan and the Rothschilds then gained control over U.S. government bond financing. Wall Street, the nest of London's U.S. partners, was fast becoming dictator of American politics, credit, and business life.

The Morgan family's attitude towards America's innovation and nation-building may be gleaned from a letter from J.P. Morgan to his father, Junius, April 29, 1874:

"I have come to the conclusion that neither my firm nor myself will have anything to do, hereafter, directly or indirectly, with the negotiation of securities of any undertaking not entirely completed. . ." [quoted in Ron Chernow, *The House of Morgan*, New York: Atlantic Monthly Press, 1990, p. 37].

Edward H. Johnson, Edison's business manager, from Philadelphia's political nationalist leadership group, led the 1884 Edison coup against J.P. Morgan.

Edison's Rise

The Philadelphians' George Barker, chief scientist for the Franklin Institute, was put in touch with Edison during the Automatic Telegraph days. Professor Barker invited Edison to demonstrate his work at the University of Pennsylvania and the National Academy of Sciences, which the Philadelphia grouping had founded during the Civil War.

From then on, the Philadelphians boosted Edison towards fame and success; Paul Israel documents much of this, although abstracted from its broader context.

Ed Johnson oversaw Edison's telephone development, in which Edison's carbon transmitter transformed Alexander Graham Bell's ineffective instrument into a commercial technology. Professor Barker made Edison famous at a National Academy of Sciences speech delivered by the phonograph, Edison's new invention, and with Washington demonstrations arranged by the nationalist faction. Ed Johnson managed the early Edison phonograph company.

The light project began soon afterwards, when Edison went out West on an astronomy excursion with Barker. The professor reviewed the evolution of electrical science, and the recent attempts to create light from electricity, and proposed that Edison take this up as his own great project. Barker next took Edison to Connecticut to view an arc light and a primitive generator installation. Seeing a problem posed, and that no one was on the track to a solution, Edison excitedly took up the challenge. A month later, Edison told the newspapers he had "invented the electric light," and would supply light and power to the dark world.

It was then that J.P. Morgan moved in to try to exercise control, and because of Morgan's increasing domination of the nation's credit, Edison was forced to deal with him. He constantly jousted with Morgan, with the (now financially weaker) Palmer group behind him and in his management. Only a fragment of these formative developments are in the Paul Israel biography, but his treatment of the initiative from this point on has broad interest.

We learn that young men worked for Edison for little or nothing, for the chance to learn, and many would be willing to pay for the privilege; Edison set up an electrical engineering school within the enterprise. Israel describes in depth the invention of the electrical industry, with teams of sub-inventors in a small group of companies and shops.

Edison constantly drew down profits to advance development, as he and his men learned to tame current.

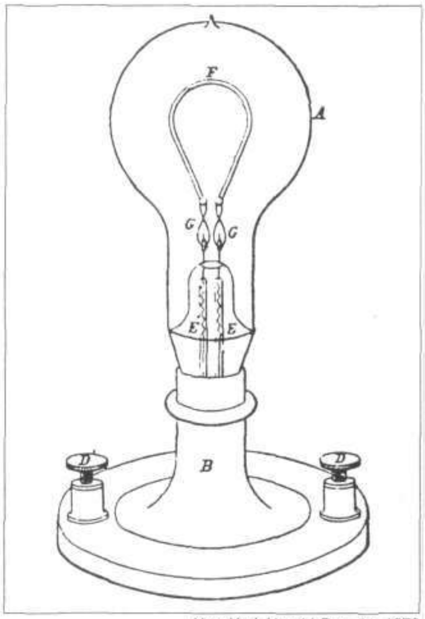
Ed Johnson went to London and established the first commercial central station in the world, the Holborn Viaduct. Johnson exhibited Edison's work at the London Crystal Palace Exhibition in spring 1882. The *London Daily News* reported: "His exhibition is the wonder of the show. . . . There is but one Edison and Johnson is his prophet."

Israel's biography shows that Samuel Insull, who was to pioneer the creation of Edison's electric utilities, was recruited into the Edison organization by the Philadelphians Gouraud and Johnson in London. And that Frank Sprague, who would engineer the large electric installations, worked first for Ed Johnson. Johnson was later president of Sprague's own company, introducing America's electric elevators, streetcars, and subways.

Morgan Applies the Brakes

When Edison successfully started up the Pearl Street, New York, central power station, J.P. Morgan let it be known that there would be no more such stations built.

An 1883 report of the Edison Electric Light Company, written by Morgan rep-



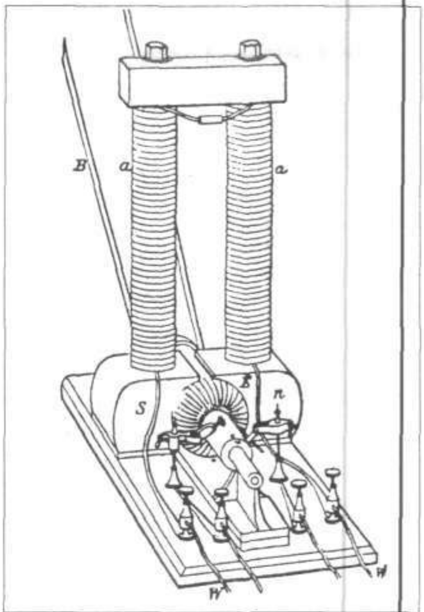
New York Herald, Dec. 21, 1879

Conceptual drawing of Edison's first successful incandescent light. In earlier experiments, he had tried rigging the current to switch off temporarily each time the filament got too hot

resentative Sherbourne Eaton, says, "the policy of the Company thus far has been merely to perform the duties of owner of the Edison patents, and to derive income from licenses and royalties thereunder."

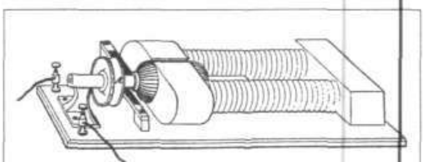
Biographer Israel comments on the showdown with Morgan: "Whereas Edison was committed to central stations as the basis of the electric light industry and as the primary customers for his shops, Eaton found that it was difficult to establish local illuminating companies 'because people will not go into them until our big central station on Pearl St. is a success, and because they take so much capital.'. . . Edison Electric . . . [was] allowing the central station business to lag until Edison decided to promote it himself. . . .

"Edison therefore decided in March 1883 'that if the business is to be made a success it must be by our personal efforts and not by depending upon the officials of our companies.' He announced that he was 'going to be simply a business man for a year. I am now a regular contractor for electric light plants, and I am going to take a long vacation in the matter of inventions. . . .' That same month, . . . he wrote Johnson to urge him to return from England to help with the new business. . ."



New York Herald, Dec. 21, 1879

Experimental design of an early working Edison generator.



New York Herald, Dec. 21, 1879

The generator constructed as a motor, "capable of performing light work . . . may be used either with or without the electric light."

As the Morgan-controlled company squeezed harder against development, Edison and his allies staged a successful rebellion. Israel quotes Edison: "We sought in a most determined way to induce our friends in the parent company . . . to join us in the undertaking. In this we signally failed. We thereupon determined upon taking all the risks and carrying the burden ourselves to the best of our ability—more with an object to make the Edison electric light a success than to make money by manufacturing."

Israel adds, "by 1883 'it [was] admitted by all' that if Edison had not [independently of Morgan] undertaken the manufacturing the Edison lighting business would have been seriously impaired."

There was a proxy fight between Ed Johnson and Morgan at the parent company's stockholders' meeting in October 1884. Morgan was temporarily defeated, and Edison determined that "Johnson would have full control of the business." Edison now worked at a superhuman pace to create the electrical industry, with Johnson and and Insull running the business. Their lightning success, and that of Edison partners overseas, helped launch our modern world.

Morgan's Usury

Israel provides vivid evidence of Morgan's usury. In the late 1880s, when Edison finally lost control of his company, he asked assurances from financier Henry Villard that Morgan would not have a controlling interest, "his experience being that when money was required for the business it was next to impossible to get it so long as Drexel Morgan & Co. controlled the business, or if obtainable at all the money could only be got at ruinous rates." Edison felt that if they were "able to exercise control the value of his property would be very seriously affected . . . and . . . that he would on no account want to place himself in a position where Drexel Morgan & Co. could squeeze any interest he owned."

Israel signals the crushing of Edison's career by Morgan, with these lines: "Alfred Tate claimed that Edison was so deeply hurt by the merger that formed General Electric and removed his name from the company that he declared, 'I'm going to do something now so different and so much bigger than anything I've ever done before people will forget that my name ever was connected with anything electrical.' "

But although motion pictures were later mainly Edison's invention, he really did not do anything "much bigger" than he had done under the old regime. He worked faithfully as an inventor and gadfly, until his death in 1931.

The London-New York axis and its corporate cartels had crippled America's mission; and their historians, until now, have not shed much light on the whole struggle. Paul Israel's book has good material which will help us to construct a competent account, but there is much more to be done.

Anton Chaitkin is director of history intelligence for Executive Intelligence Review. *Among his many American historical studies are the books* Treason in America: From Aaron Burr to Averell Harriman *and* George Bush: The Unauthorized Biography.

Seeing America's Ancient History

by Allen Douglas

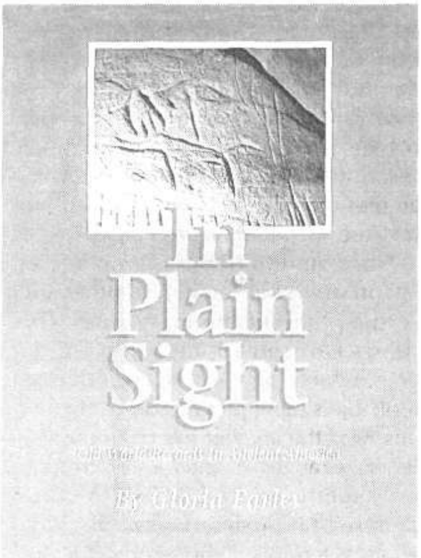
In Plain Sight:
Old World Records in Ancient America
Gloria Farley
Columbus, Ga.: ISAC Press, 1994
Hardcover, 483 pp., $37.00

This remarkable book was 11 years in the writing, and 45 years in the researching. It presents 338 pieces of evidence, supported by 540 photographs and scale drawings, and 893 references, to demonstrate that Europeans and North Africans visited America before Christopher Columbus. If one opens the book somewhat skeptical of such contact—which is still fiercely denied by "mainstream" archeologists and anthropologists—by the end of its 483 pages, one has developed the eyes to see what is, indeed, "in plain sight."

Its author, Oklahoma housewife-turned-epigrapher Gloria Farley, was a close collaborator of the founder of the Epigraphic Society, Barry Fell, for almost 20 years, beginning the day they first met, in 1975, at Harvard University. Shortly before Fell's death in 1994, he had just finished reviewing the pre-publication proof copy, and he remarked to Farley: "I could not put it down. I am so glad you wrote it."

Gloria Farley's career as a self-educated pioneer epigrapher began at age 12, when she first saw "Indian Rock" in her home town of Heavener, Oklahoma. This large rock was covered with what were later proved to be Viking runestones from 750 A.D. In the two decades before she met Barry Fell, Farley found hundreds of other, non-runic inscriptions (in 22 different scripts) and hundreds of petroglyphs (pictures on stone), virtually all of which were along the Mississippi River and its tributaries, such as the Arkansas, Poteau, and Cimarron Rivers—the pathways along which early visitors would obviously travel.

Fell's linguistic genius provided the keys to unlock Farley's treasure trove of scrupulous records, and the result is her ground-breaking book. Her collaboration with Fell was extraordinarily fruitful, and she soon found carved stones all the way from Vermont in the north-

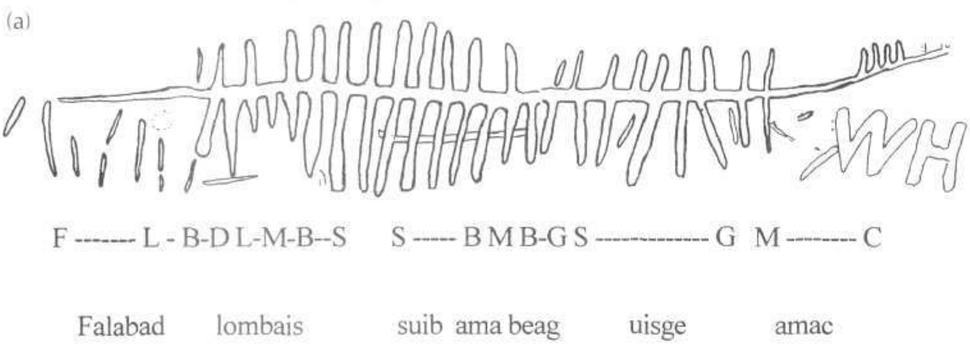


eastern United States, California, many of which were translated by Fell, and appear in this book.

Plow Marks—or Ancient Writing?

In his 1976 book, *America B.C.,* Barry Fell has nothing but ridicule for those who dismiss the extensive evidence of inscriptions on stone, which he and his

(a)



(b)

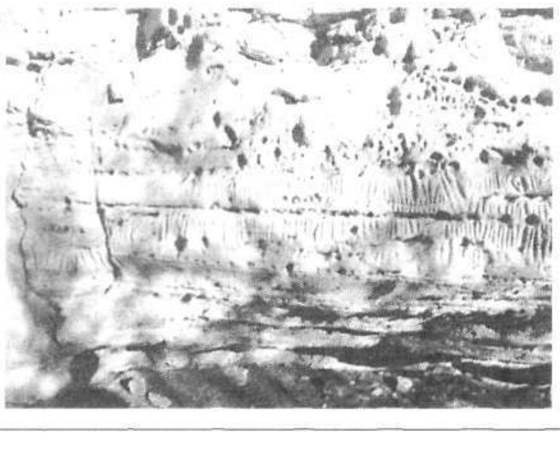


Figure 1
OGAM INSCRIPTIONS

The Ogam writing system is of ancient Celtic origin, and Ogam inscriptions are found throughout Europe and North Africa. Barry Fell's transliteration and translation of an Ogam inscription from Picture Canyon, Colorado appear in (a). Shown in (b) is a section of 70 feet of Ogam writing in western Oklahoma, photographed by Mark Farley.

Source: *In Plain Sight*, pp. 209-210.

collaborators uncovered and translated, as "plow marks" or "Indian art." In fact, Fell consulted extensively with farmers about the kinds of marks made when plows hit rocks, which bear no resemblance to the sorts of clearly alphabetic inscriptions he was working with. (Examples of ancient Ogam "grooved writing" are shown in Figure 1.)

Nor could Indians write in ancient Egyptian, Phoenician, and other such scripts. One of the more interesting things Fell and Gloria Farley discovered, which, on the surface of it, might look like simple pictures drawn by Indians, was the ancient use of "rebuses"—letters arranged in such a way as to not only spell a word, but also to draw a picture of it. A simple example Farley gives of a rebus is the word "chicken." (see Figure 2).

There is also an actual example of a rebus translated by Fell, for "Ship of Ra," the Egyptian sun-god (Figure 3). This inscription was found in Picture Canyon, Colorado. Fell explained that it was a ship rebus in the ancient Berber language, using connected Numidian letters. The letters spell "Ra Safina," which means "Ship of Ra." All told, Gloria Farley found 48 different petroglyphs of ships, 34 of which are published in her book.

Figure 2
A SIMPLE REBUS EXAMPLE
A rebus uses the letters spelling the object pictured.

Source: *In Plain Sight*, p. 15

The Caves of Anubis

Perhaps Farley's most interesting discovery involves a series of five caves in western Oklahoma, which contain a wealth of Old World inscriptions, many featuring the Egyptian god of the afterlife, the jackal-god, Anubis. (A picture of Anubis from one of those caves is featured on the cover of her book.) When she first walked into Cave Two, and saw the extensive inscriptions on the wall, she exclaimed, "This is Egyptian!" Her companions, looking at the dog-like image she was pointing out, laughed and said, "That is just a coyote,"—a common sight in that part of

Continued on page 83

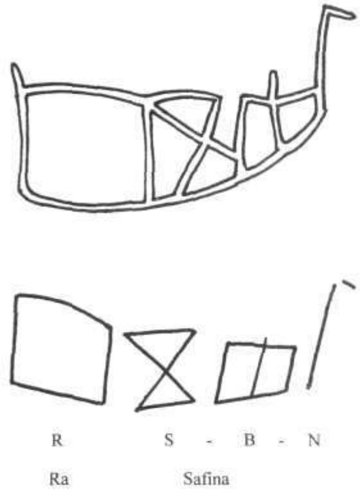


Figure 3
FELL'S DECIPHERMENT OF THE REBUS SHIP PETROGLYPH
Barry Fell deciphered this ship petroglyph from Picture Canyon, Colorado (above) as letters in the ancient Berber language, "RSB-N," (below), which stand for Ra Safina, or Ship of Ra (the Sun god). As Fell explains, the sounds of "B" and "P" are interchangeable.

Source: *In Plain Sight*, p. 16

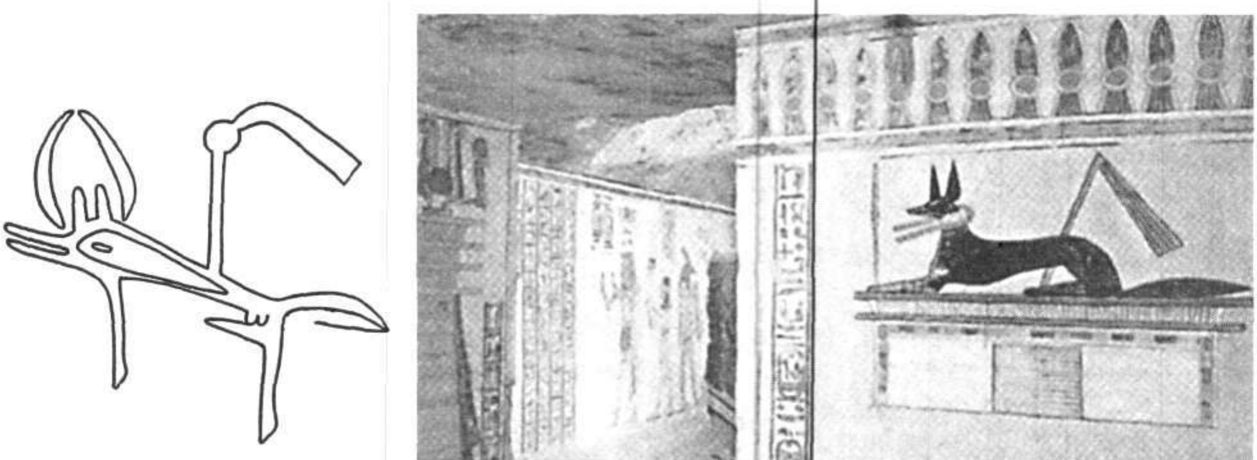


Figure 4
ANUBIS IN EGYPT—AND OKLAHOMA
This depiction of Anubis with the royal flail is from a postcard of the tomb of Chamwes in Luxor, Egypt. Farley recognized Anubis in an Oklahoma cave drawing, which is shown on the cover of her book in a photograph, and here in a tracing.

Source: *In Plain Sight*, frontispiece and p. 89

Old World Travel to Ancient America

by Michael Skupin

Courtesy of Mark McMenamin

A Carthaginian gold stater, minted around 330 B.C. This coin is part of the series of Carthaginian gold coins that bears the map of the Old and New Worlds. Coins later in the series have the map.

Phoenicians in America 350 B.C.
Mark McMenamin
South Hadley, Mass.: Meanma Press, 1999*
Paperback, 2 Vol., $40

Only a couple of years ago some of the most owlish nooks of the Internet were roiled by a brouhaha of astonishing rancor, on the normally nerdy subject of ancient coinage. The acrimony was occasioned by two publications of Mark McMenamin, the author of the book being reviewed here: The article "Cartography on Carthaginian Gold Staters" (a stater is a kind of coin), appeared in the venerable journal *The Numismatist* (November 1996), and a self-published (Meanma Press, 1996) monograph, titled Carthaginian Cartography: A Stylized Exergue Map (exergue is the technical term for the space below a coin's central design, usually on the "tail" side).

McMenamin, a professor of geology at Mt. Holyoke College, had suggested that certain hitherto-unexplained designs on Carthaginian coins are in fact maps, and that these maps include some localities in the New World, and hence are evidence (if not proof), that in their heyday the Carthaginians had crossed the Atlantic.

He thereby stepped squarely on a tripwire: Among older archeologists the idea of pre-Columbus contact between the Old World and the Americas is a strictly enforced taboo, even as a thought-experiment. Thus, the mud-wrestling.

It was during a lull in the fighting that yours truly entered the picture: I interviewed Prof. McMenamin for an archaeology monthly in Spain (via the Internet; we have never met). The interview was a lively one, and I was very impressed with his originality and the depth of his investigations in the arcane realm of archaeonumismatics, or in plain English, ancient coins. Now I find myself reviewing an amplified version of these ideas in the volumes under discussion; the reader may have gathered that I would like to recommend these books as a good introduction to an interesting historical question.

Alas, I cannot. The normally engaging McMenamin has laid an egg with this effort: Its style is the murkiest of profspeak, its organization is topsy-turvy, and it contains several serious scholarly sins. I will get through the autopsy as quickly as I can.

In support of my allegation of clumsy writing, I note that Volume 1 has about a hundred pages of text, but 476 footnotes; Volume 2 has 360 footnotes for about 80 pages. I could rest my case right here, but since I must be cruel only to be kind, I hereby complain not only of the quantity of the footnotes, but their quality, zeroing in on notes 182, 186,

The Evidence from Phoenician Coins

Mark McMenamin's newest book, Phoenician Coins and Their Countermarks, *in press, describes the latest information on the Carthaginian coins. Here, McMenamin summarizes his thesis.*

Numismatic evidence favoring the hypothesis of a Carthaginian presence in North America has recently come to light. The evidence is twofold. The first piece of evidence consists of a particular group of early Carthaginian gold coins, called staters, that bear a map showing both the Old World and the New World. Going from east to west, the maps show India, the south coast of Europe above Sardinia and Sicily, and America.

The second piece of evidence consists of a series of seven or eight copper coins found scattered across North America from Nebraska to Georgia to Connecticut. The coins have an image of the Punic horse, the Phoenician palm tree (very curiously, uprooted as if it is about to be transplanted), and an enigmatic inscription in the Punic language. It seems unlikely that these coins were brought across the Atlantic in modern times, and they thus seem to suggest a Carthaginian presence in ancient America.

Taken separately, these pieces of evidence could be dismissed as some type of fluke or hoax, respectively. But taken together, along with the fact that Carthaginian gold and copper coins were reported from the Azores in 1778, the available evidence strongly suggests that the Carthaginians had the ability to cross the Atlantic at will.

and 338 in the first volume.

Note 186 cites not a scholarly source, but a witticism of contemporary humorist P. J. O'Rourke. I am not making this up.

Note 182 straight-facedly (and, I hope, unwittingly) memorializes Louis H. Gray's 1923 article on the Carthaginian snippets in Plautus's play *Poenulus.* Fie! Gray's article is the crassest, most brazen plagiarism in all Phoeniciana, and McMenamin was wrong to have cited it as anything other than a piece of knavery.

In note 338, McMenamin has entombed one of the strongest pieces of supporting evidence for his thesis; if I hadn't found it, and drawn attention to it here, I suspect that no one ever would have.

We press on. In Volume 1, Chapter 9, we find an extended and utterly irrelevant discussion of a Gustave (Madame Bovary) Flaubert novel that is set in Carthage.

In the same volume, Chapter 5, we find a discussion of *The Circumnavigation of Hanno,* a Greek text purporting to record a Carthaginian voyage down the coast of Africa. Here McMenamin simply has not done his homework: He states that Hanno "founded five cities," whereas the Greek clearly states that he "re-supplied" them: Hanno's voyage began not as a bold venture into the unknown, but as a "milk run," its high adventure starting later in the voyage.

As to the background information McMenamin gives on the Phoenicians and their Carthaginian kin in various preliminary chapters, the reader would learn just as much from an encyclopedia, and would find the writing more succinct; the professor likewise includes an overview of Phoenician grammar as Appendix A, although what this has to do with navigation is a mystery to me.

Enough. Rather than thrash through all the shortcomings of this effort, let me offer a shortcut, a thought experiment of my own: If you get rid of the bad parts of McMenamin's Carthaginians, you wind up with the same material as his fine 1996 monograph *Carthaginian Cartography.* So order that one instead.

Michael Skupin was an associate of the late Barry Fell.

Notes

* Available from Meanma Press, 63 Silver Street, South Hadley, Mass. 01075

Ancient History

Continued from page 81

America. However, as Gloria replied, "I knew that an Oklahoma coyote would not be wearing the crown of Upper Egypt and that he would not have the royal flail standing on his back." For comparison, see Figure 4, a photograph of a painting of Anubis in an ancient Egyptian tomb.

The Anubis caves project occupied many months over a number of years. Farley provided the inscriptions, Barry Fell provided the translations, and it makes a fascinating story. One of the most interesting aspects is how the entire inscription in Cave Two was designed such that on only two days of the year—the spring and autumn equinox, when the length of night and day are exactly equal—would a sunlit pointer move across the entire series of inscriptions in an obviously calculated way, which Farley records. One day before the equinox, or one day after, and the patterns of light and shadow form no coherent pattern. In fact, the work of Barry Fell and his collaborators, such as Dr. Jon Polansky and Gloria Farley, gave a major boost to the new discipline of "archaeoastronomy"—the design of ancient monuments according to sophisticated astronomical knowledge, of which Fell gives many examples in his *America B.C.*

A Story of Persistence

There is still another story to this handsome book, beyond those graven in the stones of bygone millennia. It is the story of the courage and persistence of individuals such as Barry Fell and Gloria Farley in standing up to the "slings and arrows" hurled at them by the guard-dogs of the status quo, those whom the poet Friedrich Schiller ridiculed as "singing-for-their-supper" scholars.

Farley is now 82, and hard at work on another book. Dr. George F. Carter, an eminent geographer, now 87, and also a longtime associate of Fell, summed up her efforts in his preface to *In Plain Sight:*

"Gloria has been the dedicated person, afire with determination to solve the huge puzzle, who is willing to pay any price in time and effort to add to the material available and to advance the understanding of the data gathered. That a housewife, handicapped for a long period by an invalid husband, without major funds, and not in robust health, has accomplished so much is enough to put the rest of us to shame."

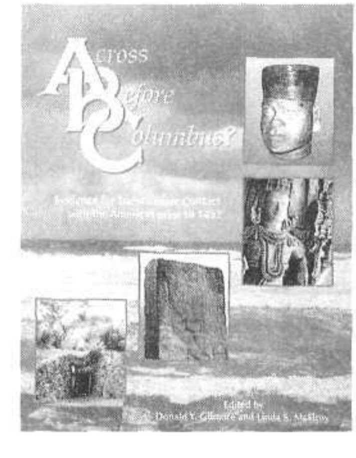
Allen Douglas writes for Executive Intelligence Review.

Notes

* Available from the author at P.O. Box 717, Heavener, Okla. 74937 for $37 plus $4 shipping.

Transocaenic Contacts with America Before the Time of Columbus

by J. Huston McCulloch



Across Before Columbus: Evidence for Transoceanic Contact with the Americas Prior to 1492
Donald Y. Gilmore and Linda S. McElroy, Eds.
Edgecomb, Maine: New England Antiquities Research Association, 1998*
Paperback, 313 pp., $26.00

This volume is a collection of 27 papers presented at the quincentennial "Across Before Columbus?" conference, sponsored by the New England Antiquities Research Association, and held at Brown University in June 1992. Most of the participants, including myself, were sympathetic to the possibility that there were numerous contacts between the Old and New Worlds before Columbus. Evidence of such contacts has generally been dismissed by professional archeologists, apart from the minimal, but now generally accepted, Viking settlement at l'Anse aux Meadows, Newfoundland.

Several of the papers relate to relatively familiar epigraphic evidence of contact from the Mediterranean or Europe. A particularly noteworthy article by David H. Kelley, a major contributor to the decipherment of Mayan phonetic writing, confirms Barry Fell's identification of North African proto-Tifinagh script—both at Peterborough, Ontario, and in Scandinavia—if not the details of Fell's proposed translations.

Suzanne Carlson provides a survey of no less than 41 purported American runic inscriptions. Of these, she identifies only 12 as clearly runic, yet not definitely modern fabrications, but this is still an impressive number. The most important of these remains the Kensington runestone from Minnesota, interest in which has been rejuvenated by Richard Neilsen's meticulous analysis of the runes, language, and numerals, and by the late Cornell linguist Robert Hall's 1994 book, *The Kensington Runestone: Authentic and Important.* Carlson provides her own translations of the controversial Spirit Pond runestones from Maine, and of the Heavener, Poteau, and Shawnee inscriptions from Oklahoma.

Semitist Cyrus H. Gordon, Professor Emeritus at both Brandeis and New York universities, surveys evidence of "Hebrew Presence in Pre-Columbian America." This includes the Smithsonian's Bat Creek Stone, which Gordon translates as reading "For Judea," in script of approximately A.D. 100; the two Decalogue inscriptions from Newark, Ohio, and Los Lunas, New Mexico; and three coins of the Bar Kokhba rebellion of the 2nd century A.D., found in Kentucky.

My own contribution to the volume is a reply to criticisms raised by certain archeologists to the validity of the Bat Creek inscription. Photographs of this artifact and the two Decalogues are on my website: http//economics.sbs.ohio-state.edu/jhm/arch/outliers.html.

Asiatic Contacts

More surprising, however, are numerous articles reporting non-epigraphic evidence of Asiatic contacts with the Americas—and vice versa. In the lead article, Smithsonian anthropologist Betty J. Meggers answers objections that have been raised to her 1966 proposal, with Clifford Evans, that Japanese Jomon pottery was introduced to the coast of Ecuador around 3000 B.C.

Anthropologist Nancy Yaw Davis provides evidence that several unique traits of the Zuni of New Mexico are the result of a 13th century A.D. contact by Buddhist missionaries from Japan. Although she does not mention it, Buddhism in America is also suggested by the hand-eye symbol that is common in the Mississippian culture of the same period. Joseph Campbell, in his book *The Mythic Image,* has pointed out that this particular symbol is intimately associated with the Boddhisatva Avalokiteshvara, the manifestation on Earth of the infinite compassion of the Buddha.

Geographer George F. Carter argues that chickens used by Amerind populations in Latin America are not of the Mediterranean type that would have been introduced by the Spanish, but rather, are distinctively Chinese and/or Malay. Amerind names for the chicken are not based on Spanish models, as one would expect. Furthermore, the indigenous Americans used their chickens for the Asian practices of sacrifice, divination, and healing, rather than as food.

My favorite paper of the entire volume is "Maize Diffused to India before Columbus Came to America," by geographer Carl Johannessen. Johannessen identifies numerous objects held in the hands of sculpted figures at several Indian temples, datable to the 11th through

Across Before Columbus, p. 216

The Kensington Stone, Kensington Minnesota. The translation of the inscription describes 8 Goths and 22 Norwegians on a "discovery-voyage from Vinland" in the year 1362.

13th centuries A.D., as maize, a crop developed in the New World after 6000 B.C. Johannessen's article is unique, in that it provides pre-Columbian evidence of the New World in the Old. A few of Johannessen's photos are linked on my web page, noted above.

Johannessen first put forward his evidence in a 1989 article with Ann Parker in the geographical journal *Economic Botany*. Critics argued that Johannessen, not being an expert on Hindu icononography or mythology, mistakenly identified as maize what surely must be something else—variously pomegranates, puffed rice balls, beaded purses, cornucopias, Muktaphala (a mythological fruit made of pearls), and even the Kalpavriksha, or mythical wish-granting tree (!), depending on the critic.

"Perhaps in the past, people were not as ignorant of the world as we—in our ignorance—have assumed them to have been."

In 1996, however, Shakti M. Gupta, an Indologist and ethnobotanist, who has written extensively on Hinduism and the role of plants in Hindu mythology, published a volume surveying plants in Indian temple art. Gupta not only confirms that Johannessen's sculptures are obviously maize, but identifies no less than *five other* New World plants in sculptures dating *as early as the 2nd century B.C.*: pineapple, sunflower, custard apple, cashew, and split leaf philodendron. Johannessen's thesis could not have been more completely confirmed.

Perhaps in the past, people were not as ignorant of the world as we—in our ignorance—have assumed them to have been.

J. Huston McCulloch is Professor of Economics and Finance at the Ohio State University at Columbus.

Notes

* The book can be ordered from NEARA Publications, Box 1050, 77 Court Street, Laconia, N.H. 03246.

Time and Astronomy Didn't Start in Babylon

by Rick Sanders

Mapping Time: The Calendar and Its History
E.G. Richards
New York: Oxford University Press, 1998
Hardcover, 438 pp., $35.00

When it comes to astronomy, the most remarkable thing about the British, as well as other old colonial aristocracy, and their hired professors, is their obsessive assertion that the first astronomers were Babylonian astrologers, who evolved into astronomers, beginning some time around 2000 B.C.—and that this was the watershed from which all other astronomy derives. That this is obsessively irrational is obvious from E.G. Richards's book *Mapping Time*. For example, compare these two statements from the book:

"Among the earliest surviving records are the great numbers of clay tablets that have been unearthed from the cities of Babylonia. The earliest are dated to about 2000 B.C. but it was not until about 400 B.C. that they record sophisticated measurements of the positions of the stars and other bodies" (p. 37).

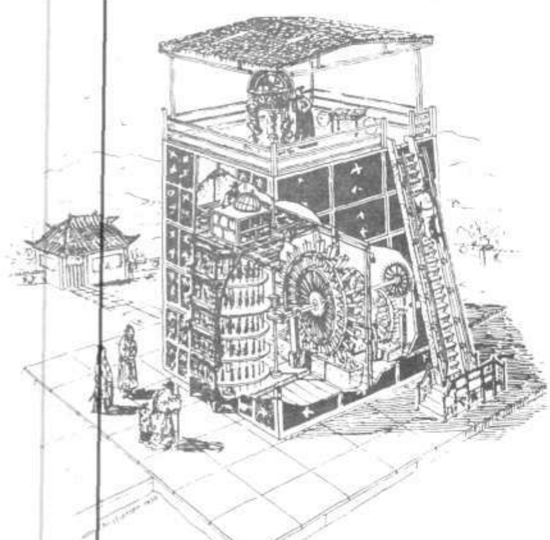
"The building of Stonehenge began in about 3100 B.C.," which he says might have been used to determine the length of the day, the days of solstice, and the helical rising of stars (p. 8).

Now, a rational person in the pursuit of truth, would try to reconcile these two contradictory statements. But this author, and the British school in general, simply cannot, so committed are they to defending the Babylonian roots of the calendar and everything else astronomical.

The poet Shelley described the mindset and heritage of this colonial crew in his poem "Ozymandias": They produce nothing of lasting value, and leave behind the record of a "sneer of cold command" captured in a fragment half-buried, where the "lone and level sands stretch far away."

No rational investigator can doubt that mankind started astronomy long before 3000 B.C. For example, there is a strong case made by a Dutch scholar

Illustration of the water clock of Chinese engineer Su Sung, built in 1090 A.D., one of many interesting illustrations in Marking Time. *The rotation of the waterwheel is controlled by a mechanism that releases the wheel when a scoop is full. The puppets (rotating at left) indicate the time. An armillary sphere at the top moves so that a star can be kept in view as the Earth rotates.*

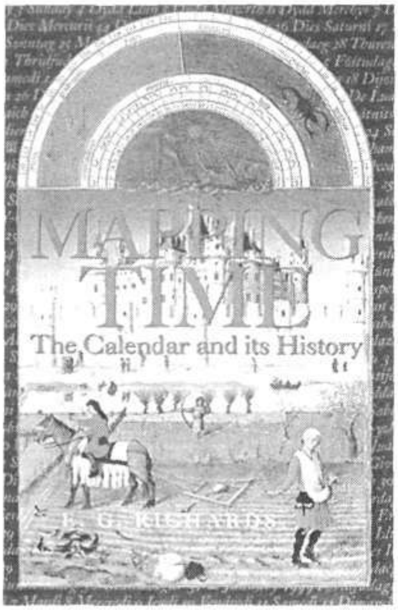


Source: *Marking Time*, p. 57

that the Chinese named their asterisms or constellations by no later than 17,000 B.C. What we already know is that Tilak, an Indian patriot imprisoned by the British in the late 1800s, proved incontrovertibly from the Vedas, that the Sanskrit speakers had identified the occurrence of spring equinox in the constellation of Orion. In other words, given the rate of precession, that part of the Vedas must have been composed by no later than 5000 B.C.

Why We Need an Accurate Calendar

Why we need an accurate calendar is a key question. An honest attempt to answer it might lead us to some astonishing new ideas. But here again, E.G. Richards gives the usual fraudulent answers, some related to agriculture, some to religion. These are gossip of the *post hoc ergo proper hoc* variety.



The fact is, that farming does not need a calendar, accurate to the *n*th decimal place of how many days in the year. The author tells, for example, of someone in England who timed the return of the cuckoo (a migratory bird) over a number of decades, and found the mean value of the intervals to be 365 days. But all the farmer needs is some tradition, and a good eye for plant and animal behavior to know when to begin sowing.

Summary verdict: Should you buy this book? No. Should you borrow it from the library? Yes, if you need a lot of information. Where else can you quickly get names of the days of the week in Old Frisian, Old Icelandic, Ukrainian, Bulgarian, Welsh, and a raft of other languages? Raw material there is here aplenty, but interlaced with ideology.

Letters

Continued from page 3

(2) Explain radiation in terms of the time to get the same effective dose from natural radiation—the Background Equivalent Radiation Time, or BERT approach (Cameron 1998a).

(3) All medical doses should be explained to patients using the BERT concept.

(4) The news media should use the BERT concept in discussing all radiation doses.

The BERT approach has several advantages:

• Patients and the public will understand the explanation.

• The explanation does not mention risk; it is a simple comparison.

• Patients will become aware that we live in a sea of radiation.

• Radiation phobia of the public will gradually decrease as the public becomes aware of the lack of risk of natural radiation.

A more in-depth explanation of the BERT concept is available on the Internet (Cameron 1998b).

John Cameron
Madison, Wisc.

References

Norman Frigerio, et al. 1974. "Carcinogenic Hazard from Low-level Low-rate Radiation," Argonne National Laboratory Report ANL/ES-26.

Robley Evans, 1974. "Radiation in Man," *Health Physics*, Vol. 27 (Nov.), pp. 497-510.

Bernard Cohen, 1995. "Test for the Linear No-threshold Theory of Radiation Carcinogenesis for Inhaled Radon Decay Products," *Health Physics*, Vol. 68, pp. 157-174.

John Cameron, 1998a. "A New Radiation Unit for the Public," *21st Century* (Spring), p. 5.

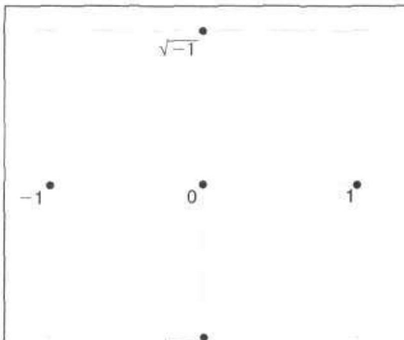
——, 1998b. "Are X-rays Safe?" http://www.medinfo.ufl.edu/other/cameron/rads.html

Corrections

The Granger Collection

This detail from an Attic painting depicting the soul of the blind prophet Tiresias (right) counseling Odysseus in Hades, published on p. 46 in the Spring 1999 issue, was mis-credited. The source of the painting was The Granger Collection.

An illustration in a book review of *An Imaginary Tale: The Story of* $\sqrt{-1}$, in the Winter 1998-1999 issue, p. 67, mislabeled one point. The corrected graphic appears here.



DEMYSTIFYING IMAGINARY NUMBERS

To make the so-called imaginary numbers real, Carl Gauss suggests that the reader draw a grid and construct a spatial depiction of the imaginary numbers. He shows that $\sqrt{-1}$ *is the mean proportional between +1 and* $\sqrt{-1}$*. A mean proportional is a value x between two numbers a and b such that a is to x as x is to b. This can be expressed algebraically as* $x = \sqrt{ab}$*. Gauss would have named the numbers direct, inverse, and lateral.*

BOOKS RECEIVED

Experimentation and Measurement
W.J.Youden
Mineola, N.Y.: Dover Publications, Inc., 1998
Paperback, 127 pp., $6.95

Paul Dirac: The Man and His Work
Abraham Pais, Maurice Jacob, David I. Olive, and Michael F. Atiyah
Cambridge: Cambridge University Press, 1998
Hardcover, 124 pp., $19.95

Children of Prometheus: The Accelerating Pace of Human Evolution
Christopher Wills
Reading, Mass. Perseus Books, 1998
Hardcover, 310 pp., $25

The Atmospheric Sciences: Entering the Twenty-First Century
National Research Council
Washington, D.C.: National Academy Press, 1998
Hardcover, 364 pp., $47.95

Towing Icebergs, Falling Dominoes, and Other Adventures in Applied Mathematics
Robert B. Banks
Princeton: Princeton University Press, 1998
Hardcover, 329 pp. $29.95

Great Feuds in Science: Ten of the Liveliest Disputes Ever
Hal Hellman
New York: John Wiley & Sons, 1998
Hardcover, 240 pp. $24.95

Out of the Crater: Chronicles of a Volcanologist
Richard V. Fisher
Princeton: Princeton University Press, 1999
Hardback, 179 pp. $24.95

A Guide to the Elements
Albert Stwertka
New York: Oxford University Press, 1999
Paperback, 240 pp., $17.95

Frankenstein's Children: Electricity, Exhibition, and Experiment In Early Nineteenth-Century London
Iwan Rhys Morus
Princeton, N.J.: Princeton University Press, 1999
Hardcover, 325 pp., $45.00

Geons, Black Holes & Quantum Foam: A Life in Physics
John Archibald Wheeler with Kenneth Ford
New York: W.W. Norton & Co., 1998
Hardcover, 380 pp., $27.95

The Garden of Ediacara: Discovering the First Complex Life
Mark A.S. McMenamin
New York: Columbia University Press, 1998
Hardcover, 295 pp., $29.95

The Biosphere
Vladimir I. Vernadsky
(David B. Langmuir, trans.)
New York: Copernicus (Springer-Verlag), 1998
Hardcover, 192 pp., $30.00

When the Earth Explodes! Volcanoes and the Environment
Buck Dawson
Commack, N.Y.: Kroshka Books, 1998
Hardcover, 275 pp., $23.95

Lysenko and the Tragedy of Soviet Science
Valery N. Soyfer
(Leo Gruliow and Rebecca Gruliow, Trans.)
New Brunswick, N.J.: Rutgers University Press, 1994
Hardcover, 381 pp., $39.95

What Have We Learned about Science and Technology from the Russian Experience?
Loren R. Graham
Stanford, Calif.: Stanford University Press, 1998
Hardcover, 179 pp., $39.50

Silencing Science
Steven Millowy and Michael Gough
Washington, D.C.: Cato Institute, 1998
Paperback, 61 pp., $8.00

Introduction to Energy: Resources, Technology, and Society
Edward S. Cassedy and Peter Z. Grossman
Cambridge: Cambridge University Press, 1998
Paperback, 427 pp., $34.95

Making Physics: A Biography of Brookhaven National Laboratory, 1946-1972
Robert P. Crease
Chicago: The University of Chicago Press, 1999
Hardcover, 434 pp., $38.00

Relativity and Its Roots
Banesh Hoffmann
Mineola, N.Y.: Dover Publications, Inc., 1999
(1983 reprint)
Paperback, 176 pp., $7.95

Stairways to the Stars: Skywatching in Three Great Ancient Cultures
Anthony Aveni
New York: John Wiley & Sons, 1999
Paperback, 230 pp., $15.95

Toward Environmental Justice: Research, Education, and Health Policy Needs
Institute of Medicine
Washington, D.C.: National Academy Press, 1999
Hardcover, 137 pp., $34.95

Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan
U.S. National Academy of Sciences, Israel Academy of Sciences and Humanities, Palestine Academy for Science and Technology, Royal Scientific Society, Jordan
Washington, D.C.: National Academy Press, 1999
Paperback, 226 pp., $35.00

Skywatchers, Shamans, and Kings: Astronomy and the Archaeology of Power
E.C. Krupp
New York: John Wiley & Sons, 1999
Paperback, 364 pp., $17.95

Mathematics: The Man-Made Universe
Sherman K. Stein
Mineola, N.Y.: Dover Publications, Inc., 1999
(1983 reprint)
Paperback, 575 pp., $18.95

Strength in Numbers
Sherman K. Stein
New York: John Wiley & Sons, 1999
Paperback, 272 pp., $16.95

Return to Mars
Ben Bova
New York: Avon Books, 1999
Hardcover, 416 pp., $25.00

Lengthening the Day: A History of Lighting Technology
Brian Bowers
New York: Oxford University Press, 1998
Hardcover, 221 pp. $45.00

Life by the Numbers
Keith Devlin
New York: John Wiley & Sons, Inc., 1999
Paperback, 214 pp., $18.95

Holding On to Reality: The Nature of Information at the Turn of the Millennium
Albert Borgmann
Chicago: The University of Chicago Press, 1999
Hardcover, 274 pp., $22.00

Earth: The Sapphire Planet
Url Lanham
Mineola, N.Y.: Dover Publications, Inc., 1999
(1978 reprint)
Paperback, 144 pp., $6.95

The Deep Hot Biosphere
Thomas Gold
New York: Springer-Verlag, 1999
Hardcover, 235 pp., $27.00

Why *Do* Buses Come in Threes?: The Hidden Mathematics of Everyday Life
Rob Eastaway and Jeremy Wyndham
New York: John Wiley & Sons, Inc., 1999
Hardcover, 156 pp., $22.95

All the Math You'll Ever Need: A Self-teaching Guide
Steve Slavin
New York: John Wiley & Sons, Inc., 1999
Paperback, 230 pp., $15.95

The Quest for Unity: The Adventure of Physics
Etienne Klein and Marc Lachieze-Rey
New York: Oxford University Press, 1999
Hardcover, 159 pp., $24.00

Gnomon: From Pharoahs to Fractals
Midhat J. Gazalé
Princeton, N.J.: Princeton University Press, 1999
Hardcover, 259 pp., $29.95

Bernhard Riemann 1826-1866: Turning Points in the Conception of Mathematics
Detlef Laugwitz (Abe Shenitzer, Trans.)
Boston: Birkhaûser, 1999
Hardcover, 357 pp., $79.50

Historical Evolution of Infrastructure: 15,000 Years of History
Demeter G. Fertis and Anna Fertis
New York: Vantage Press, 1998
Hardcover, 191 pp., $18.95

Rocket Boys: A Memoir
Homer H. Hickman, Jr.
New York: Dell Publishing, 1998
Hardcover, 368 pp., $23.95

Travels to the Nanoworld: Miniature Machinery in Nature and Technology
Michael Gross
Reading, Mass.: Perseus Books, 1999
Hardcover, 254 pp., $25.95

The Fire within the Eye: A Historical Essay on the Nature and Meaning of Light
David Park
Princeton, N.J.: Princeton University Press, 1999
Paperback, 377 pp., $16.95

The Polar Bear Strategy: Reflections on Risk in Modern Life
John F. Ross
Reading, Mass.: Perseus Books, 1999
Hardcover, 208 pp., $23.00

Mathematical Sorcery: Revealing the Secrets of Numbers
Calvin C. Clawson
Reading, Mass.: Perseus Books, 1999
Hardcover, 294 pp., $26.95

Calendar: Humanity's Epic Struggle to Determine a True and Accurate Year
David Ewing Duncan
New York: Avon Books, 1998
Paperback, 328 pp., $13.50

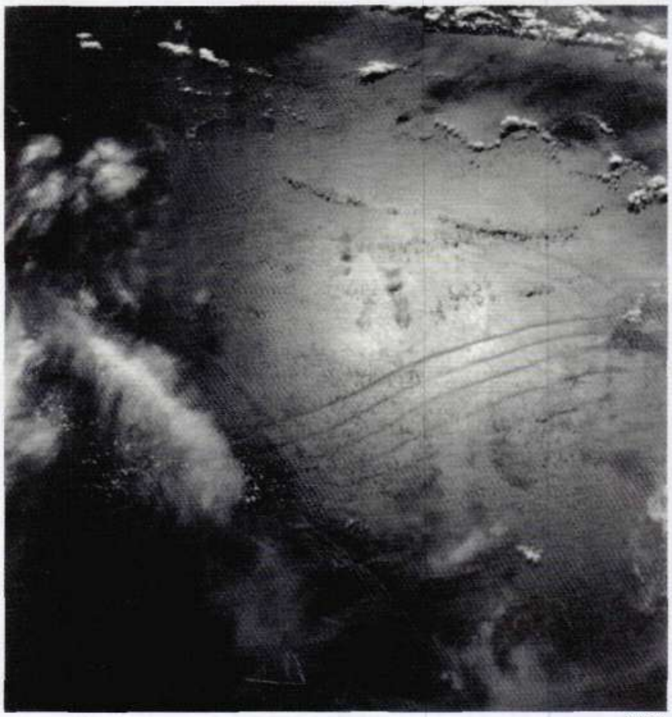
Chariots for Apollo: The Untold Story Behind the Race to the Moon
Charles R. Pellegrino and Joshua Stoff
New York: Avon Books, 1999 (reprint from 1985)
Paperback, 336 pp., $13.50

THE NEAR-SURFACE OCEAN FROM SPACE

Solitons, suloys, and spiral eddies—the dramatic, turbulent phenomena that characterize the near-surface ocean—were all discovered from space. Pioneer space oceanographer Robert E. Stevenson tells the story, noting that these nonlinear phenomena confound any linear computer models that attempt to describe ocean and climate dynamics.

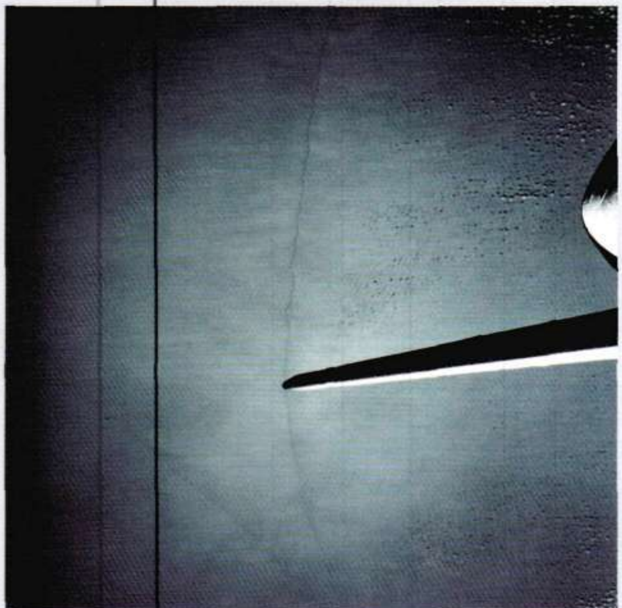
NASA

Spiral eddies in the eastern Alboran Sea, seen from the flight deck of the Shuttle Endeavor, May 1996.



NASA

Solitons seen in the Andaman Sea, photographed in 1975, from the Apollo spacecraft. The southern Andaman Islands are in the foreground; the Burma shore is at the top.



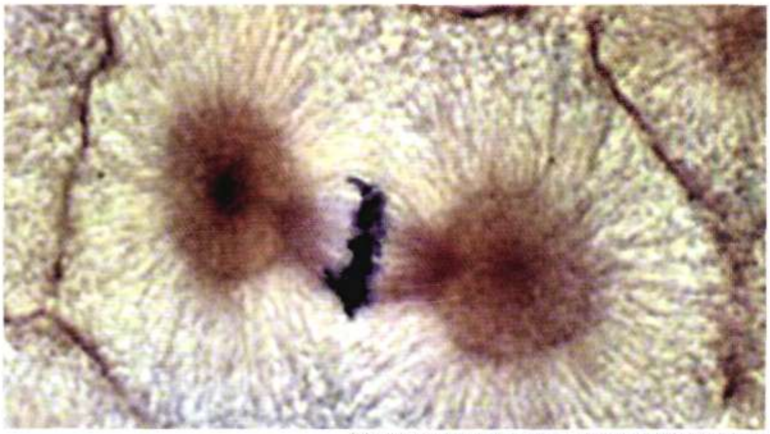
NASA

A continuous series of equatorial open-ocean suloys in the central Pacific, viewed from the flight deck of the Shuttle Atlantis, August 1992.

In This Issue:

THE VERNADSKY-GURWITSCH-BAUER SCHOOL AND A NEW BIOLOGICAL PARADIGM

Russian biologist Vladimir Voeikov demonstrates that living systems are characterized by stable non-equilibrium at all levels, a concept that goes beyond the Second Law of Thermodynamics. In making this point, he develops the theoretical and experimental foundation for a new biological paradigm, based on the work of Vladimir Vernadsky, Alexander Gurwitsch, and Ervin Bauer. As Jonathan Tennenbaum notes in his introduction, this work ran counter to the reductionist thrust of Western biology in this century, and is largely unknown in the West.

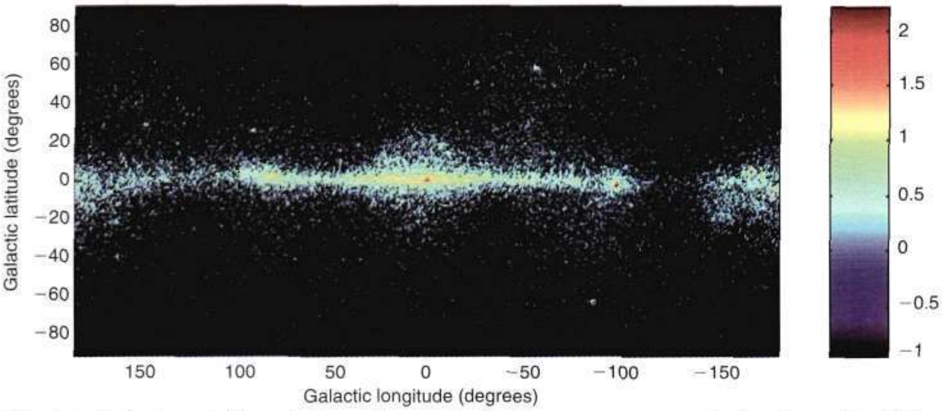


Courtesy of Jeffrey Carmichael, University of North Dakota

Development is the most unique feature of living systems. Here, the anaphase stage of mitosis in whitefish blastula.

GAMMA-RAY BURSTS DEFY ACCEPTED COSMOLOGY

Dramatic gamma-ray bursts observed by gamma ray detectors have recently made headlines, and have confounded theoreticians, because the energy spectra do not fit the usual explanations, such as "black holes" or "hypernovas." Lothar Komp reviews the past 25 years of gamma-ray burst research, the data from current gamma ray detection and observation devices, and suggests that the solution requires some new principles of physics or astronomy.



The bright horizontal band along the center is the gamma-ray emission from the Milky Way galaxy, a direct composite of four years of data from the EGRET telescope on NASA's Compton Gamma Ray Observatory. There is more brightness than can be accounted for by theoretical models. The image is generated by dividing the sky into 1/2 degree squares, and plotting the number of photons that arrived in each square; the intensity scale is logarithmic, and the red areas correspond to about 200 photons.

Source: University of California, Riverside

REVIEWING AMERICA'S ANCIENT HISTORY

What evidence exists of transoceanic contacts with America before the time of Columbus? The Books section continues the ancient discovery theme of the past two issues with reviews of (and illustrations from) three books that document such contacts: Gloria Farley's *In Plain Sight: Old World Records in Ancient America;* Mark McMenamin's *Phoenicians in America 350 B.C.;* and the New England Antiquities Research Association's conference proceedings, *Across Before Columbus: Evidence for Transoceanic Contact with the Americas Prior to 1492.*

Continued on inside back cover

Photo by Mark Farley, *In Plain Sight*, p. 209

An example of Ogam writing, an ancient Celtic script, found on rocks in western Oklahoma.